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Volume 17 Number 11

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

NOVEMBER 1933

JACKSON GROUP OF FORMATIONS IN TEXAS WITH NOTES ON FRIO AND VICKSBURG[1]

ALVA CHRISTINE ELLISOR[2]
Houston, Texas

ABSTRACT

The Jackson formation of Texas is raised to the rank of a group, and a new nomenclature is given for the various formations and members of this group. The three formations of the Jackson, namely, Whitsett, McElroy, and Caddell, are subdivided into members. Sections of the Jackson from Atascosa County to Sabine County are given, showing the variation in the sections, the unconformities, and the overlaps. Subsurface sections are given to show the persistence of these formations across Texas, to show the relationship of the surface to the subsurface, and to show the unconformities at the top of the Jackson. A section is given to establish the stratigraphic position of the Frio and to show the presence of the Vicksburg in Texas.

INTRODUCTION

The purposes of the writer are: to introduce a new nomenclature of the Jackson group of formations, to show the stratigraphic sequence and relationship of the three formations of the Jackson group, to correlate the surface with the subsurface formations as nearly as possible, to show the position of the Vicksburg formation, and to establish the age of the Frio clays.

ACKNOWLEDGMENTS

The problem of correlating the Jackson across the state of Texas was first assigned to the writer in 1928 by E. Holman. At that time field work was done with Olin G. Bell and Kenneth Owen in the Laredo area, with L. F. McCollum in the San Antonio area, and with Frith Owens, G. Moses Knebel, L. W. MacNaughton, and C. L.

[1] Presented before the Association at the Houston meeting, March 24, 1933. Manuscript received, July 17, 1933.

[2] Research geologist for the Humble Oil and Refining Company.

Rankin in East Texas. Later more detailed work was done with L. P. Teas, S. O. Burford, Perry Olcott, Sam Houston, G. Gierhart, and Henry McCallum. Burford and Olcott mapped the Jackson formations in detail from Trinity County east in 1932, and Sam Houston mapped the Whitsett formation in detail through Gonzales, Karnes, and Atascosa counties. Their coöperation has greatly assisted the writer. The writer is indebted to F. W. Rolshausen and other members of the Humble laboratory for their assistance.

J. A. Cushman devoted much of his time to comparing the fossils with types in his laboratory and describing new species.

F. B. Plummer and Helen Plummer gave valuable assistance.

The writer is indebted to L. T. Barrow and to the directors of the Humble Oil and Refining Company for their permission to publish this paper.

HISTORY

The formations here discussed were first described by Penrose[3] in 1890. The name Fayette was given by Penrose to include all beds above the Cook Mountain and below the Lagarto formation.

Kennedy[4] in 1891 discussed the Fayette sands. He stated:

> A region of country extending from the south side of the Neches southward to and beyond Corrigan as far as Rockland, is occupied by a series of gray sands, sandstones, and gray and white clays. Toward the west the sandstones forming the northern boundary of the beds are found near Pennington, in Trinity County; on White Rock Creek on the southern line of Houston County, and outlying portions appear near Weldon in the same county. The southern line extends from the Neches several miles south of Rockland, westward to and beyond the Trinity, outcrops being found near Summit in Tyler County, Stryker in Polk County, and at Phelps in Walker County.
>
> Three miles north of Corrigan, on the line of the Houston East and West Texas Railway, a deposit of white limestone occurs containing casts of shells. The fossils found here have been referred to the Eocene by Dr. Dall on the strength of the existence of the cast of what appears to be a *Cardita planicosta*.

The Fayette of Kennedy included the three Jackson formations of this paper and the Catahoula sands.

Veatch[5] in 1902 recorded the Jackson formation in Texas for the

[3] R. A. F. Penrose, Jr., "A Preliminary Report on the Geology of the Gulf Tertiaries of Texas from Red River to the Rio Grande," *Texas Geol. Survey 1st Ann. Rep.* (1890), pp. 47–58.

[4] Wm. Kennedy, "A Section from Terrell, Kaufman County, to Sabine Pass, on the Gulf of Mexico," *2d Ann. Report of Texas* (1891), pp. 60–62.

[5] A. C. Veatch, "The Geography and Geology of the Sabine River." A report on the geology of Louisiana. *Louisiana State Exp. Sta., Geol. Agr. La.*, pt. 6, *Spec. Rept. 3* (1902), pp. 131–32.

GENERAL POSITION OF
THE JACKSON FORMATIONS
MILES
OLIGOCENE
COCKFIELD
YEGUA
CLAIBORNE
WILCOX

FIG. 1

first time. He stated that a typical Jackson fauna had been found ¾ mile below Robertson's Ferry on Sabine River on the Texas side.

The considerable thickness of the Jackson beds here indicated that careful search would reveal Jackson in Texas, and recent work has shown Jackson fossils near Caddell Post Office in clayey marls and in the white sandstone directly above them.

Dumble[6] in 1918 discussed at length the Jackson formation which he divided into the Manning beds, the Caddell beds, and the Wellborn beds. In his discussion of the Fayette sandstones in this report Dumble placed the age as Claiborne.

In 1924 Dumble[7] still considered the Fayette as Claiborne in age. In this report he separated the former Fayette of type section into two series, the Lipan beds, which he called Claiborne, and the Whitsett beds, which he correlated with the Jackson as found in the vicinity of Caddell and White City.

Deussen[8] was the first to place the age of the Fayette sandstone as Jackson. He stated:

The evidence at hand does not indicate that the Fayette sandstone is of lower Claiborne age. It has not been possible to find the lower Claiborne faunas reported from these sandstones north of the Nueces. Though most of the fossils are poorly preserved and difficult to identify there is nothing about them that suggests their affinity with the lower Claiborne. On the contrary such specimens as have been collected, including *Ostrea georgiana* and *Tellina eburniopsis*, suggest Jackson affinities rather than Claiborne. Furthermore the fossil leaves collected from the formation point decidedly to an age later than the lower Claiborne. It seems fairly certain, therefore, that the Fayette sandstone is not of lower Claiborne but of Jackson age. . . .

It would, therefore, seem that the Fayette sandstone is a stratigraphic unit of Jackson age, which has its greatest development in southwestern Texas and becomes thinner eastward toward Louisiana.

Deussen gives the stratigraphic position as follows.

In the region west of Brazos River the Fayette sandstone lies conformably above the Yegua formation but in eastern Texas and western Louisiana it lies above the Jackson.

West of Colorado River it is overlain conformably by the Frio clay but east of Colorado River it is conformably overlain by the Catahoula sandstone.

[6] E. T. Dumble, "The Geology of East Texas," *University of Texas Bull.* (1918) pp. 145–84.

[7] E. T. Dumble, "A Revision of the Texas Tertiary Section with Special Reference to the Oil-Well Geology of the Coast Region," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8 No. 4 (July–August, 1924), pp. 424–44.

[8] Alexander Deussen, "Geology of the Coastal Plain of Texas West of Brazos River," *U. S. Geol. Survey Prof. Paper 126* (1924), pp. 83–84.

Deussen[9] considered the Wellborn the base of the Fayette west of the Brazos, putting the Caddell in the Yegua.

Cushman and Applin[10] published a paper in 1926 on the Texas Jackson *Foraminifera*, in which they divided the Jackson formation into three major zones, the *Textularia hockleyensis* zone, *Textularia dibollensis* zone, the *Bulimina jacksonensis* zone, and several minor zones (the *Discorbis jacksonensis*, var. *texana* zone, *Textularia distortio* zone, and *Nonionina whitsettensis* zone).

In 1931 the present writer presented a paper on the Jackson group of formations before the annual meeting of the Association at San Antonio, and twice previously, once before the San Antonio Geological Society and once before the Houston Geological Society, in which the Fayette formation was redefined and limited to the upper formation of the Jackson group.

The United States Geological Survey, in the preliminary map of Texas, published in 1932, showed the Fayette to include the entire Jackson group of formations. On this map the name Jackson, which has priority, was not used, and the name Fayette was used for the entire series between the Claiborne and the Oligocene. Therefore, the name Fayette as used by the writer has to be dropped, and another name substituted.

STRATIGRAPHY

After surface and subsurface study, the series of beds between the Claiborne and the Oligocene can be divided on the basis of micropaleontology and lithology into three major divisions or formations, which were designated by the writer[11] in 1931 as the Diboll, McElroy, and Fayette. Diboll has since been changed to Caddell.

As the United States Geological Survey has used the name Fayette as synonymous with the name Jackson and is using the name Fayette to include all the Jackson sediments, F. B. Plummer, of the Bureau of Economic Geology, University of Texas, suggested dropping the name Fayette for the upper, third formation of the Jackson group. As the name is now applied as a group name it can not be delimited to a formation. The name Whitsett has been selected for the former Fayette of the writer.

The three major divisions, namely, the Caddell, the McElroy,

[9] Alexander Deussen, oral report to the writer.

[10] J. A. Cushman and E. R. Applin, "Texas Jackson Foraminifera," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 2 (February, 1926), pp. 154–89.

[11] Alva C. Ellisor, "Jackson Formation of Texas," manuscript read before the Paleontology and Mineralogy Division of the Association, at the San Antonio meeting, March 20, 1931.

and the Whitsett formations, can be traced by subsurface methods from Sabine River to the Rio Grande. On the surface the lithologic character changes from east to west. For field purposes these major formations have been divided into minor horizons or zones and names applied to each. The following is a table of the divisions discussed in this paper.

CLASSIFICATION CHART

Group	*Formation*	
Oligocene	Frio	
	Vicksburg	
Jackson	Whitsett	Olmos sand
		Fashing clays
		Calliham sand
		Dubose sands and clays
		Stone's Switch sand
		Falls City shales
		Dilworth sand
	McElroy	Manning beds
		Wellborn sands
		Wooley's Bluff clays
	Caddell	Upper chocolate phase
		Lower marl phase

CADDELL FORMATION

E. T. Dumble,[12] in 1915, proposed the name Caddell for the calcareous clays in the vicinity of Caddell, San Augustine County, Texas. He described the section as follows.

From the valley of Ayish Bayou westward the base of the Jackson was more easily determined by reason of the occurrence of a series of dark clays with greensand and calcareous concretions carrying fossils. The line thus given crosses the St. Louis and Southwestern Railway north of White City. The Angelina River two miles north of Caddell follows the line of the St. Louis and Southwestern Railway to Donovan and crosses the Texas and New Orleans Railway just south of Prestidge, and the Houston East and West Texas Railroad in the vicinity of Diboll. In the area east of the railway the general section of the Jackson from a number of sections and traverses of Baker and Suman shows:

At the base are greenish clays and sandy clays with some sand and greensand which are iron-stained. These weather dark brown and carry calcareous concretions. The concretions contain more or less sand and greensand, are geodic in places, and they carry Jackson invertebrate fossils and remains of plants. These are overlain by grayish-brown, sandy clays with seams of sulphur, which are followed by buff, sandy clay with plant remains and gray, drab clays with gypsum and sulphur. Excellent exposures of these beds are found around the town of Caddell, San Augustine County, and that name is proposed for this stage.

[12] E. T. Dumble, *Bull. Geol. Soc. America*, Vol. 26 (1915), p. 462.

Other exposures of Caddell were given by Dumble as follows.

West of the Houston East and West Texas Railway we find the Caddell clays with fossiliferous, calcareous concretions on Tar Kiln Creek, some five miles southwest of Diboll, at which place well-preserved fossils were collected, and it outcrops again about twelve miles northeast of Groveton, on the Georgetown, Lufkin and Northern Railway. From Tar Kiln Creek, four miles southwest of Diboll, an abundant invertebrate fauna is present including *Haminea grandis*.

The Caddell is exposed around the station of White City, San Augustine County. On the highway ½ mile north of Pineland, Sabine County, is an easily accessible exposure of the typical blue, glauconitic, sandy clays of the Caddell, containing calcareous modules and weathering yellow. At some places between White City and Pineland a distinct bed of sandy limestone is present.

The Caddell, on the basis of lithology, can be divided into the lower marly phase and the upper chocolate-colored clay phase.

The lower or marly phase of the Caddell is easily recognized because of its distinctive blue and green clays which weather yellowish and contain many small calcareous nodules though the sandy calcareous concretions are not present. It is highly fossiliferous.

At the base of the Caddell occurs a zone of "*Operculina oliveri*" Cushman, easily recognized in the field. This zone has been traced from Caddell through White City, Yellow Ridge in San Augustine County, across Sabine County from ½ mile north of Pineland through Yellow Pine to Veatch's locality on Sabine River ¾ mile below Robertson's Ferry. From here it has been traced across Louisiana into Moody's Branch marl at Jackson, Mississippi.

From White City, San Augustine County, the Caddell has been traced across Angelina County through Diboll and across Trinity County. Exposures of the lower phase of the Caddell are found in the town of Diboll and 4 miles east of Diboll on Stoval Creek. In the western part of Trinity County the Caddell loses its highly calcareous character. Near Friday, Trinity County, in a bluff on Caney Creek on the Tipton farm, is an exposure of blue massive clay containing concretions of greensand with pyrite fossil casts, above which is a slightly sandy blue clay with carbonaceous streaks.

On Tantabogue Creek where the Trinity-Lovelady Highway crosses the creek are exposures of the chocolate-colored clay phase and also in the area south of Pennington. On the new Lovelady-Trinity Highway north of Tantabogue Creek are exposures of the marly phase of the Caddell.

Across Walker County and Grimes County only weathered phases

of the Caddell have been noted. North of Carlos are a few exposures. In Brazos County west of Wellborn are good exposures of a chocolate-colored clay but no *Foraminifera* have been found. On Brazos River at Koppe's Bridge, in Brazos County occurs an outcrop of the Caddell. The section as given by Dumble[13] shows:

	Feet
1. Dirty brown clay with layer of dark brown limonitic concretions 5 feet from base. Fossils at base	15–20
2. Brownish gray, fossiliferous clay, showing limonite layers 1/16–1/4 inch thick. Near top it contains beds of sand 1 inch thick	6
3. Lignitic clay interbedded with yellow clay. Some limonite concretions. Balls and lenses of lignite showing manganese in cracks. Few light-to-dark gray concretions of siderite	4
4. Interbedded sands and clays. Beds of clayey sandstone mark base of section. The layers are 1–3 inches thick, well bedded, poorly indurated, coarse-to-medium greenstand; color, dirty white-to-greenish white. Middle is more argillaceous, whiter, thin bedded, with layers of lignite 1 inch thick. Upper 3 feet more sandy, thin bedded, and showing stains of limonite. Silicified wood plentiful in these beds	10

The Caddell can be traced through to Atascosa County but the outcrops are poor. In Fayette County north of Muldoon at Lena Spur The Texas Company has mined the Caddell for fullers earth. In Gonzales County the marly phase is recognized north of Dilworth and south of Smiley. On the road south of Smiley at the cross-roads on the F. R. Mauldin 108-acre tract in the Peter Winn Survey is a highly fossiliferous, highly calcareous exposure. On Guadalupe River in the south corner of Mrs. A. J. Hilderbrand's tract in the Jonathan Cottle Survey is an exposure of the Caddell. North of Dilworth is an excellent exposure on the highway on the Rud Bartsch 200-acre tract in the J. S. Butler Survey.

Across northern Karnes County the Caddell can be traced by the reddish brown weathered soil so typical of the Caddell. On the San Antonio-Corpus Christi Highway from a point approximately 1.3 miles north of the Karnes-Wilson County line the marly phase outcrops with fossiliferous sandstone concretions as seen south of Smiley. In Atascosa County the Caddell is much weathered and can be recognized mainly by the reddish brown soil and calcareous concretions. There is an outcrop on the north side of the road leading westward from the main highway, and on the north line of the International and Great Northern Railway Survey No. 537½.

The Caddell rests conformably on the Cockfield and is overlain by the McElroy on the surface east of Trinity County and unconformably by the Wellborn sandstones west of Trinity County. In wells it can be traced from Sabine River to the Rio Grande. The

[13] E. T. Dumble, "The Geology of East Texas," *Univ. Texas Bull.* (1918), p. 151.

Caddell varies in thickness from 150 to 300 feet. The ordinary thickness is 200 feet. The Caddell includes the *Textularia dibollensis* zone of Cushman and Applin. The *Bulimina jacksonensis* zone of Cushman and Applin is the same as the *Textularia dibollensis* zone.

The foraminiferal fauna of the Caddell is plentiful and includes the following species.

FORAMINIFERAL FAUNA OF CADDELL FORMATION

Ammobaculites agglutinans (d'Orbigny)
Ammobaculites hockleyensis Cushman and Applin
Anomalina bilateralis Cushman
Anomalina jacksonensis (Cushman and Applin)
Anomalina jacksonensis (Cushman and Applin), var. *texana* (Cushman and Applin)
Bathysiphon filiformis M. Sars
Bolivina gracilis Cushman and Applin
Bolivina jacksonensis Cushman and Applin
Bulimina jacksonensis Cushman
Bulimina pyrula d'Orbigny
Buliminella subfusiformis Cushman
Cassidulina subglobosa Brady
Cibicides cf. *ungerianus*
Cibicides lobatulus (Walker and Jacob)
Cibicides yazooensis Cushman
Dentalina cf. *cocoaensis* Cushman
Dentalina pauperata d'Orbigny
Discorbis hemisphaerica Cushman
Eponides jacksonensis (Cushman and Applin)
Gaudryina advena Cushman
Glandulina laevigata (d'Orbigny)
Glandulina laevigata (d'Orbigny), var. *ovata* (Cushman and Applin)
Globigerina bulloides d'Obigny
Globorotalia cocoaensis Cushman
Guttulina hantkeni Cushman and Ozawa
Guttulina irregularis (d'Orbigny)
Guttulina problema d'Orbigny
Hantkenina alabamensis Cushman
Haplophragmoides dibollensis Cushman and Applin
Lagena cf. *striata* d'Orbigny
Lamarckina ocalana Cushman
Marginulina fragaria Gümbel, var. *texasensis* (Cushman and Applin)
Marginulina glabra (d'Orbigny)
Marginulina jacksonensis (Cushman and Applin)
Nodosaria jacksonensis Cushman and Applin
Nodosaria spinescens (Reuss)
Nodosaria vertebralis (Batsch) H. B. Brady
Nonion inexcavatum (Cushman and Applin)
Nonion micrus Cole
Nonion umbilicatulum (Montagu)
Nonionella hantkeni (Cushman and Applin), var. *spissa* Cushman
Operculina oliveri Cushman
Planularia cf. *wuellerstorfi* (Schwager)
Plectofrondicularia mexicana (Cushman)
Robulus alato-limbatus (Gümbel)
Robulus articulatus Reuss, var. *texanus* (Cushman and Applin)
Robulus cf. *alato-limbatus* (Gümbel)
Robulus cf. *cultratus* Montfort
Robulus propinquus (Hantken)
Saracenaria italica (Defrance)
Sigmomorphina jacksonensis (Cushman)

CLASSIFICATION OF THE JACKSON GROUP

ALVA C. ELLISOR
MARCH 1932

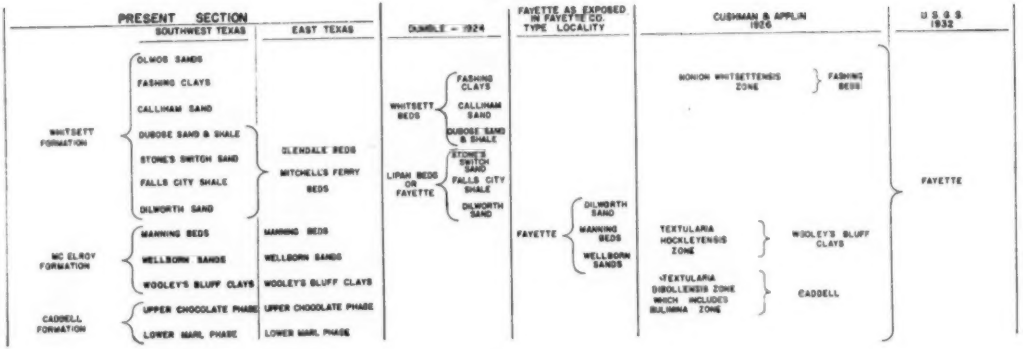

FIG. 2

Sigmomorphina jacksonensis (Cushman), var. *costifera* (Cushman)
Siphonina advena Cushman, var. *eocenica* Cushman and Applin
Siphonina jacksonensis Cushman and Applin
Textularia cf. *mexicana* Cushman
Textularia dibollensis Cushman and Applin
Textularia mississippiensis Cushman
Textularia mississippiensis Cushman, var. *alabamensis* Cushman
Textularia mississippiensis Cushman, var. *rhomboidea* Cushman and Ellisor
Tubulogerina eocenica Cushman and Ellisor
Uvigerina alata Cushman and Applin
Uvigerina gardnerae Cushman, var. *texana* Cushman and Applin
Uvigerina pygmaea d'Orbigny
Uvigerina topilensis Cushman
Virgulina dibollensis Cushman and Applin

McELROY FORMATION

Stratigraphically above the Caddell and below the Whitsett occurs the McElroy formation, consisting of three mappable units or zones: Wooley's Bluff clays, Wellborn sandstones, and Manning beds.

The type locality of the McElroy formation is in Sabine County, Texas, on the Gulf, Colorado and Santa Fe Railroad on the north edge of Achelles, E. C. Johnson headright, about 5 miles north of Brookeland. The McElroy consists of a series of light chocolate-brown plastic clays with thin seams of sulphur-yellow stained sands; bluish gray, marly, glauconitic clays, which weather yellow; fossiliferous sands; lignitic, sandy, brown shales, and beds of volcanic ash and glass.

On the surface a marine zone (Wolley's Bluff clays) is separated from the upper nonmarine lignitic zone (Manning beds) by fossiliferous sandstones (Wellborn sands) which overlap the lower zone west of Angelina County. For field work it has been found desirable to name these mappable units, which are as follows.

Wooley's Bluff clays.—Several years ago Alexander Deussen gave the writer a sample of very fossiliferous clay of Jackson age from a bluff on Caney Creek back of the old Wooley home in Sabine Parish, Louisiana, in Sec. 4, T. 3 N., R. 12 W. The bluff is here designated Wooley's Bluff, and is selected as the type locality for the Wooley's Bluff clays. About 5 feet of highly fossiliferous, sandy, glauconitic, marly, blue clays weathering yellowish brown, and 10 or more feet of light chocolate-brown clays are exposed in this bluff. As the weathered surface of Wooley's Bluff clays is identical in character with that of the Caddell, it is difficult to differentiate the two units in the field.

In Texas this zone is less marly but is characterized by fossiliferous, limonitic concretions and casts of pelecypods and gastropods. The zone of *Pinnas*, found at the type locality, can be traced across Sabine, San Augustine, and Angelina counties.

The type locality of the *Textularia hockleyensis* zone of Cushman and Applin is on the Wooley's Bluff clays in San Augustine County. Another good exposure is on the Long Bell Lumber Company's 5,000-acre tract, Stephen Stanley Survey, Angelina County. Exposures of the highly fossiliferous Wooley's Bluff clays are not numerous. The chocolate-colored clays containing *Textularia hockleyensis* Cushman and Applin are well exposed in Sabine County on the highway between Pineland and McElroy, and in San Augustine County on the Dead Highway 1½ miles west of Sandy Creek in the P. Lewis Survey and the W. Lakey Survey. In Angelina County exposures are found on the highway between Lufkin and Zavalla in the railroad cuts in the vicinity of Shawnee. West of Angelina County the Wooley's Bluff clays disappear on the surface, and the Wellborn rests unconformably on the Caddell overlapping the lower McElroy. The Wooley's Bluff clays range from 250 to 300 feet in thickness.

The foraminiferal fauna of the Wooley's Bluff clays is plentiful and includes the following species.

FORAMINIFERAL FAUNA OF WOOLEY'S BLUFF CLAYS

Anomalina bilateralis Cushman
Anomalina jacksonensis (Cushman and Applin)
Anomalina jacksonensis (Cushman and Applin), var. *texana* (Cushman and Applin)
Bolivina beyrichi Reuss, var. *carinata* Hantken
Bolivina gracilis Cushman and Applin
Bolivina jacksonensis Cushman and Applin
Cibicides lobatulus (Walker and Jacob)
Cibicides yazooensis Cushman
Dentalina cocoaensis Cushman
Dentalina jacksonensis Cushman
Discorbis farishi Cushman and Ellisor
Eponides jacksonensis (Cushman and Applin)
Globigerina bulloides d'Orbigny
Guttulina irregularis (d'Orbigny)
Guttulina problema d'Orbigny
Guttulina spicaeformis (Roemer)
Marginulina fragaria Gümbel, var. *texasensis* (Cushman and Applin)
Marginulina pediformis Bornemann
Massilina decorata Cushman
Massilina humblei Cushman and Ellisor
Nodosaria jacksonensis Cushman and Applin
Nodosaria vertebralis (Batsch)
Nonion chapapotensis Cole
Nonion whitsettensis (Cushman and Applin)
Pseudopolymorphina dumblei (Cushman and Applin)
Quinqueloculina seminula (Linné)
Robulus articulatus (Reuss), var. *texanus* (Cushman and Applin)
Robulus limbosus (Reuss), var. *hockleyensis* (Cushman and Applin)
Sigmomorphina jacksonensis (Cushman)
Siphonina advena Cushman, var. *eocenica* Cushman and Applin
Textularia hockleyensis Cushman and Applin
Textularia mississippiensis Cushman
Uvigerina alata Cushman and Applin
Uvigerina cocoaensis Cushman
Uvigerina pygmaea d'Orbigny

Wellborn sandstones.—Above the Wooley's Bluff clays occur the Wellborn sandstones, defined by Kennedy[14] in 1892. In this report on Grimes, Brazos, and Robertson counties, he described the Wellborn as follows.

These sandstones, with their accompanying gray sands, although here tentatively denominated the Wellborn beds, belong to and help to form a part of the series of gray sands and sandstones extending across the state from Neches River in Polk County as far west as Sunnyside church in Lee County.

In Grimes County the gray sands and sandstones form an irregularly defined belt of varying width extending across the country from the edge of the Navasota bottom lands on the east to the Brazos River on the west. They are hard, close-grained, and compact, occasionally showing a tendency to become quartzitic. The country occupied by them is generally flat and prairie-like, covered by gray sand, and few outcrops or continuous ledges of the sandstone can be seen anywhere.

Small outcrops occur at several places on the Sam Davidson and James Hope leagues on the western side of the country, where the belt has an apparent width of nearly three miles. These outcrops are irregular in areal extent and thickness, and appear usually as isolated patches or "knoles," surmounting the small rounded hills forming the uplands of this region. The sandstones here rest upon the upper beds of the lignitic sands and clays found farther north. A section on a small creek on the south side of the James Hope headright shows:

1. Gray sand and gravel	1 foot
2. Gray sand, with great quantities of silicified wood	5 feet
3. Gray indurated sand with ledges of soft sandstone	10 feet
4. Gray sandstone jointed and thinly-bedded	8 feet
5. Dark brown lignitic clay, showing yellow streaks and sulphur efflorescence	20 feet

Near the mouth of White's Creek the gray sandstones are seen capping the higher grounds. Here these sands are arranged in three ledges, showing an aggregate thickness of 20 feet, and rest upon the dark brown clays of the lignitic deposits. No fossils have been obtained from them except a few small dicotyledonous leaves, but their direct continuity with the fossil-bearing sandstone has been traced along a series of small outcrops across the country by way of Minter Springs and Wellborn to the junction of the two on the R. Stephenson league.

Going east from Wellborn, light gray clays and thin beds of sandstone appear in the cuttings and washouts along the south side of the R. Stephenson league for a distance of several miles. About three miles to the southeast of the station, at Dr. Williams' quarry, on the same league, an exposure of regularly-bedded gray sandstone appears along the north bank of a small stream. The general section of this place appears to be:

1. Gray sands, showing some distance down the creek	2 to 8 feet
2. Thinly-laminated light gray (almost white) sandy clays	2 to 8 feet
3. Broken deposit of sandstone containing fossils	2 feet
4. Regular and even-bedded gray fossiliferous sandstone	6 feet

[14] Wm. H. Kennedy, *Geol. Survey of Texas, 4th Ann. Rep.* (1892), p. 45.

Kennedy found the following fossils which were identified by Harris.[15]

Cancellaria penrosei Harris
Corbula alabamiensis Lea
Cylichna kellogii (Gabb)
Cytherea bastropensis Harris
Pleurotoma quassalis
Venericardia planicosta Lamarck
Yoldia claibornensis Conrad

Kennedy traced the Wellborn beds from Neches River in Polk County to Sunnyside Church in Lee County.

On Neches River on the highway between Corrigan and Lufkin is found a fossiliferous exposure of the Wellborn on the Wooley's Bluff clays. From this point east to Sabine River the Wellborn lies on the Wooley's Bluff clays. West of Neches River the Wooley's Bluff clays gradually disappear and the Wellborn rests unconformably on the Caddell.

The Wellborn in Fayette County is well exposed at Muldoon. Here the three ledges are exposed, forming a well-defined escarpment.

In Gonzales County an excellent exposure of the Wellborn is found on Guadalupe River 6 miles below Gonzales. The following section is given by Deussen.[16]

	Thickness Feet
Gray cross-bedded sand	2
Impure kaolin-like clay	6
Hard gray sandstone	4
Gray sand with mud cracks	6
Gray sand with several thin beds of fossiliferous sandstone; specimens of *Tellina eburniopsis* Conrad?	10
Very hard sandstone	$\frac{1}{2}$
Soft, slightly glauconitic, fossiliferous sand, specimens of *Tellina eburniopsis* Conrad?	3
Hard sandstone	$\frac{1}{2}$
Soft, slightly glauconitic sand	$\frac{1}{2}$
Hard, dark, sandy clay	$\frac{1}{2}$
Gray yellow sand	1
Gray sand	50
	$83\frac{3}{4}$

In Karnes County the Wellborn is exposed north of Cesthowa on Cibolo Creek near the county line. The Wellborn can be traced across Atascosa County, but no detailed sections have been made by the writer.

[15] G. D. Harris. In E. T. Dumble's "Geology of East Texas," *Univ. Texas Bull.* (1918), p. 148.

[16] Alexander Deussen, "Geology of the Coastal Plain of Texas West of Brazos River," *U. S. Geol. Survey Prof. Paper 126* (1924), p. 87.

Dumble[17] in 1918 stated that the type locality of the Fayette was on Colorado River in the extreme western corner of Fayette County. His locality of the Yegua-Fayette contact on Colorado River is the Wellborn-Caddell contact. Therefore the type locality of the Fayette is in the Wellborn sandstones, according to Dumble.

Manning beds.—Stratigraphically above the Wellborn occur a series of beds here designated as the Manning beds. Dumble [18] described a Manning section which included more beds than are referred to as the Manning beds of this paper. The Manning beds of this paper include all beds stratigraphically above the Wellborn sands and below the Dilworth sands.

In the vicinity of Manning, Angelina County, are exposed the Wellborn sandstones. In a cut about 100 yards southeast of the depot at Manning there is an exposure of thinly bedded fossiliferous Wellborn sandstone. East of Manning is a low hill capped by coarse-grained, medium-hard, light gray, massive sandstone which belongs also to the Wellborn sands. About 3 miles south of Manning exposures of the Dilworth sands are found along an old tramroad, and east and west of it. Above a massive, medium-textured, gray-to-brown, indurated sand occurs thin, flaggy, fossiliferous, fine-textured sand, which is the Dilworth sand. Between these two sandstone series occur the Manning beds from Sabine River to Atascosa River. The beds consist of lignitic chocolate-brown shales with thin partings of sand; brown, carbonaceous sands; tuffaceous sandstones and beds of volcanic ash and cross-bedded glass; chocolate-brown, diatomaceous shales, and brown bentonitic shales.

In Trinity County good exposures are found along the Groveton, Lufkin and Northern Railroad, north of Groveton.

> At Mile Post 8 and immediately to the south there is a cutting exposing about ten feet of a chocolate-brown, carbonaceous, shaly clay, thin-bedded and containing leaf impressions. Near the middle of the section is three inches of a grayish to yellowish-brown, cross-bedded sandstone.[19]

An excellent exposure of cross-bedded, volcanic glass is found along the railroad cut of the Houston East and West Texas Railway at Wakefield, Polk County. A good section of the Manning beds is seen on the Lufkin-Corrigan Highway south of Neches River. In Angelina County south of Zavalla good outcrops occur in the cuts on the highway to Rockland and on the highway to Jasper. These lignitic shales, with

[17] E. T. Dumble, "Geology of East Texas," *Univ. Texas Bull.* (1918), p. 134.

[18] *Op. cit.*, p. 176.

[19] *Op. cit.*, p. 166.

beds of volcanic glass and ashy sandstones, are exposed across the northern part of Walker County; across Grimes, Brazos, southern Burleson, northern part of Washington, Fayette, Gonzales, Karnes, and Atascosa counties.

In Brazos County exposures are found south of Wellborn on the road to Millican, and in Fayette County excellent exposures are found in the several creeks south of Muldoon. In Gonzales County a good section is found on the old highway south of Smiley, whereas in Karnes and Atascosa counties there are few good sections, due to weathering.

The Manning beds are essentially non-fossiliferous. In East Texas *Textularia hockleyensis* Cushman and Applin is found, though it is usually distorted. In the wells near the outcrop the McElroy is equivalent to the Manning beds. *Textularia hockleyensis* and a few arenaceous species are found, usually *Ammobaculites hockleyensis* Cushman and Applin. Farther down the dip both the Manning beds and the Wooley's Bluff clays are present in wells from Sabine River to Rio Grande.

Although *Textularia hockleyensis* is the characteristic fossil of the McElroy, it has been found to range up into the Whitsett (Fayette). Therefore, in the wells the first appearance of *Textularia hockleyensis* does not necessarily indicate the McElroy.

The foraminifer *Massilina pratti* Cushman and Ellisor, which occurs in the basal part of the Whitsett formation, is a better horizon marker than *Textularia hockleyensis* Cushman and Applin.

As previously stated, the Manning beds are essentially nonmarine sediments with a few beds having a scant fauna. At the close of this period the sea invaded the entire area, depositing a body of sand, which is sharply marked off from the nonmarine sediments of the Manning and forms the basal bed of the marine Whitsett formation. This sandstone has been designated the Dilworth sand. With our present information the Dilworth sand seems to be correlative with the base of the Whitsett formation, which will be discussed later.

The Wellborn sands and the Manning beds have been considered a part of the Fayette. The field work of S. O. Burford and Perry Olcott from Trinity County to Sabine River established these beds as the equivalent of the upper part of the McElroy, which overlaps the Wooley's Bluff clays or the lower part of the McElroy west of Angelina County.

The McElroy formation in the wells consists of dark brownish gray, fossiliferous shale with lenses of sand. The lower half, which corresponds with the Wooley's Bluff clays, is highly fossiliferous, whereas

the upper part has a scant fauna, and in the western part of the area described becomes very sandy.

The McElroy formation in the wells varies in thickness from 300 to 1,000 feet, the average being 700 feet in the basin.

The list of the *Foraminifera* in the McElroy formation includes the following species.

FORAMINIFERAL FAUNA OF McELROY FORMATION

Ammobaculites hockleyensis Cushman and Applin
Anomalina bilateralis Cushman
Anomalina jacksonensis (Cushman and Applin)
Anomalina jacksonensis (Cushman and Applin), var. *texana* (Cushman and Applin)
Bathysiphon filiformis M. Sars.
Bolivina beyrichi Reuss, var. *carinata* Hantken
Bolivina gracilis Cushman and Applin
Bolivina jacksonensis Cushman and Applin
Bulimina jacksonensis Cushman
Bulimina pyrula d'Orbigny
Buliminella alabamensis Cushman
Buliminella elegantissima (d'Orbigny)
Buliminella subfusiformis Cushman
Cibicides lobatulus (Walker and Jacob)
Cibicides yazooensis Cushman
Dentalina cocoaensis Cushman
Dentalina jacksonensis Cushman
Discorbis farishi Cushman and Ellisor
Eponides jacksonensis (Cushman and Applin)
Globigerina bulloides d'Orbigny
Globulina gibba d'Orbigny
Guttulina irregularis (d'Orbigny)
Guttulina problema d'Orbigny
Guttulina spicaeformis (Roemer)
Hantkenina alabamensis Cushman
Haplophragmoides dibollensis Cushman and Applin
Marginulina fragaria (Gümbel), var. *texasensis* (Cushman and Applin)
Marginulina jacksonensis (Cushman and Applin)
Marginulina pediformis Bornemann
Massilina decorata Cushman
Massilina humblei Cushman and Ellisor
Nodosaria jacksonensis Cushman and Applin
Nodosaria vertebralis (Batsch)
Nonion chapapotensis Cole
Nonion micrus Cole
Nonion whitsettensis (Cushman and Applin)
Nonionella hantkeni (Cushman and Applin)
Pseudopolymorphina dumblei (Cushman and Applin)
Quinqueloculina seminula (Linné)
Robulus alato-limbatus (Gümbel)
Robulus articulatus (Reuss), var. *texanus* (Cushman and Applin)
Robulus cultratus Montfort
Robulus limbosus (Reuss, var. *hockleyensis* Cushman and Applin)
Sigmomorphina jacksonensis (Cushman)
Siphonina advena Cushman, var. *eocenica* Cushman and Applin
Textularia carinata d'Orbigny
Textularia hockleyensis Cushman and Applin
Textularia mississippiensis Cushman
Uvigerina alata Cushman and Applin
Uvigerina cocoaensis Cushman
Uvigerina gardnerae Cushman, var. *texana* Cushman and Applin
Uvigerina pygmaea d'Orbigny

WHITSETT FORMATION

In 1931 the writer[20] used the name Fayette for the upper, third formation of the Jackson group of formations. The United States Geological Survey, on the geological map of Texas issued in 1932, used the name Fayette to include all of the Jackson group. As Fayette had been printed on the map to include all the Jackson series, F. B. Plummer advised that a new name should be given to the upper, third formation.

The name Whitsett was given by Dumble[21] in 1924. He stated:

In the separation of the former Fayette of type section into two series, the lower or true Fayette, which we still hold to be Claiborne, has been called the Lipan beds, and the upper, the Whitsett beds.

Above the hard sandstone which marks the top of the Lipan escarpment we find beds of greenish-gray and yellow waxy or carbonaceous clays and sandy clays with some of the chocolate color interbedded with yellow, gray, pink, and brown sands. These sands, on the whole, are not so prominent and are finer than those of the Lipan, and not so hard. Beds of volcanic ash occur. The formation is characterized by the presence of opalized wood and chalcedony. Aragonite in cone-in-cone concretions or imbedded form is common. Dark colored septarial concretions, the joints and cracks of which are filled with quartz crystals, occur throughout the beds. These beds carry fossils in many places, and have an estimated thickness of more than 500 feet.

Unfortunately Dumble did not give a type locality for his Whitsett beds. The section which Dumble[22] described in 1902 in a bluff 90 feet in height, on the east bank of Atascosa River, near Whitsett's house in Section 48, Reiffert and Forbese 109-acre tract of the Juan Houligan Survey, is included within the Whitsett formation (in the Dubose zone) as it is here used in this paper, and is selected by the writer for the type locality of the Whitsett formation.

The section is as follows.

SECTION AT TYPE LOCALITY OF WHITSETT FORMATION

	Feet
1. Gray sandstone, weathering yellow	2
2. Sandstone, from 2 to 6 inches thick, interbedded with laminated sands in bands from 2 to 10 inches in thickness	10
3. Cross-bedded brown sands, fossiliferous, laminated in places	3
4. Interbedded and interlaminated clays and sands, weathering in light colors like Fayette materials elsewhere	15
5. Light brown sand-rock-like segregation of cone-in-cone	6

[20] "Jackson Formation of Texas," manuscript read before the Paleontology and Mineralogy Division of the Association at the San Antonio meeting, March, 20, 1931.

[21] E. T. Dumble, "A Revision of the Texas Tertiary Section with Special Reference to the Oil-Well Geology of the Coast Region," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 4 (July–August, 1924), pp. 424–44.

[22] E. T. Dumble, "Geology of Southeast Texas," *Trans. Amer. Inst. Min. Eng.* (1902), p. 947.

6. Fossil-bed, with partings of gypsum crystals..... 3
7. Same as No. 5..... 11
8. Lignitic clays and sands with efflorescence of sulphur..... 6
Detritus—covered to creek.

The Whitsett formation of this paper includes all beds from the top of the Manning beds of the McElroy formation to the base of the Frio; therefore, it includes the Lipan beds and the Whitsett beds of Dumble.

In the wells a large unconformity exists at the top of the Whitsett east of the Atascosa and Karnes county line. On the surface in addition to this unconformity the beds are progressively overlapped by the Catahoula so that in Fayette County south of Muldoon and east for a distance the Whitsett formation is completely covered by the Catahoula. As the geology has not been mapped in detail between Fayette and Trinity counties, it is impossible to state exactly how much of the Whitsett is exposed. From Trinity County east the lithologic character of the Whitsett changes from the section found in Atascosa County or type section. The Whitsett rests conformably on the McElroy.

The Whitsett varies in lithologic character across the state, and can be divided on the surface into lithologic zones as well as paleontologic zones. The following names are given to these zones.

WHITSETT FORMATION

Southwest Texas	*East Texas*
Olmos sand	
Fashing clays	
Calliham sand	
Dubose sands and shale	Glendale beds
Stone's Switch sand	Mitchell's Ferry beds (*Massilina pratti* zone in wells)
Falls City shale	
Dilworth sand	Dilworth sand

Sam Houston has mapped in detail the Whitsett formation from Atascosa through Karnes and Gonzales counties. His measured section of the Whitsett formation from Whitsett in Live Oak County north toward Campbellton, Atascosa County, is shown in Figure 3. He estimated the Whitsett to be about 550 feet thick.

DESCRIPTION OF WHITSETT ZONES

Dilworth sand.—The deposition of the Manning beds was brought to a close by an invasion of the sea which deposited from Atascosa to Sabine County a sand remarkably uniform in physical characteristics in the entire area.

Perry Olcott, when mapping the Jackson formation in Angelina

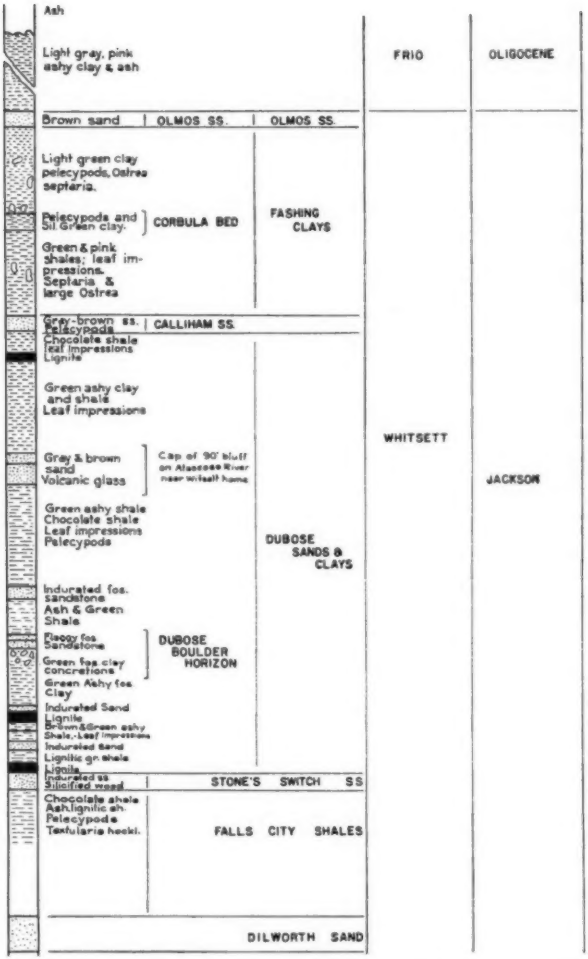

FIG. 3.—Surface section of Whitsett formation in vicinity of Whitsett, Atascosa County, Texas. Measured by Sam Houston. Vertical scale: 1 inch = 100 feet.

County, discovered a thin flaggy quartzitic sandstone that crops out persistently across the county into Sabine County. Later he and S. O. Burford traced this sandstone across Polk and Trinity counties. Olcott and Burford referred to this bed as the "F.F.Q." bed (fossiliferous flaggy quartzite). Olcott found an excellent exposure in the creek bottom at the head of Burris Creek in Angelina County. On the Crockett Highway this flaggy quartzite is exposed in the railroad cut 3 miles northwest of Trinity. In Angelina County in cuts along the Zavalla-Jasper Highway excellent exposures are found 3–6 miles east of Zavalla.

This flaggy quartzite has been traced west of Trinity County in reconnaissance work only. By its uniform lithologic character and its usual position above the Wellborn, as shown in section *DD*, Burford, in reconnaissance work with the writer, has verified its presence across Grimes, Brazos, and Fayette counties and at Dilworth in Gonzales County. In East Texas this flaggy quartzite unfortunately does not crop out near any town or landmark. For this reason, only, the writer has selected Dilworth in Gonzales County for the type locality. Here the section[23] is as follows.

SECTION OF DILWORTH SAND 0.8 MILE EAST OF BRICK SCHOOLHOUSE IN DILWORTH, ON J. WINCLAREK 39.5-ACRE TRACT IN GEO. BLAIR SURVEY

	Feet	*Inches*
Thin, flaggy, ripple-marked sandstone, 1 inch or 2 inches thick, having pelecypod casts alternating with layers of green clay and volcanic glass 1 inch to 2 inches thick	8	
Green clay	2	
Thin, flaggy, very fine-grained sandstone		3
Green, bentonitic shale	4	
Thin, flaggy, fine-grained sandstone		2
Loose sand with green clay inclusions	2	6
Chocolate, thinly laminated shale with streaks of sand	2	
	18	11

The Dilworth sand has been roughly traced across Gonzales, Karnes, and Atascosa counties. In Gonzales County it is exposed north of Cheapside on the east line of the J. S. Douglass 150-acre tract in the Hendricks Survey and south of Smiley on the old road on the Mrs. Alice Culpepper 416-acre tract in the George Gwinn Survey. In Karnes County the Dilworth sand is exposed at Cesthowa and on the road from Cesthowa to Falls City. Very fossiliferous exposures are found in Atascosa County on the Campbellton-Falls City road in the J. R. Baker Survey just across the county line and south of Campbellton on the highway to Whitsett.

[23] Measured for the writer by Sam Houston.

On comparing the surface intervals of the Whitsett with the intervals as found in wells close to the outcrop and by tracing the *Massilina pratti* zone in the wells to the surface, it is found that the Dilworth sand marks approximately the base of the Whitsett. The Dilworth sand marks the beginning of marine conditions.

Falls City shale.—Stratigraphically above the Dilworth sand in Fayette, Gonzales, Karnes, and Atascosa counties is a series of chocolate-colored bentonitic shales and carbonaceous shales with thin lenses of sand, in places fossiliferous. As *Textularia hockleyensis* Cushman and Applin is found in these shales, it is advisable to name them so as to differentiate them from the McElroy. In addition to *Textularia hockleyensis* Cushman and Applin, typical Whitsett species are found, namely, *Nonion laevis* (d'Orbigny), var. *marginatum* Cushman and Ellisor, *Valvulineria texana* Cushman and Ellisor, *Nonionella hantkeni* (Cushman and Applin), var. *fayettei* Cushman and Ellisor, and *Anomalina jacksonensis* (Cushman and Applin), var. *limbosa* Cushman and Ellisor.

The type locality of these shales west of Falls City is in the bed of San Antonio River forming the falls of the river. Fossiliferous exposures are found in a bluff on San Antonio River on the Herman Rabe tract in the Don G. Seguin Survey about 5 miles from Falls City, also in a bluff on the F. J. Kraweitz 100-acre tract in the Menchaca Survey east of San Antonio River. In the same shales exposed in a road cut on the J. Moczygamba 247-acre tract in the D. C. Flores Survey, F. W. Rolshausen found *Massilina pratti* Cushman and Ellisor in addition to *Textularia hockleyensis* Cushman and Applin. *Massilina pratti* is very limited at this locality, for Rolshausen was unable to locate this fossil here on later visits. Its presence is here mentioned so future workers may look for it.

Stone's Switch sand.—A prominent sandstone horizon occurs above the Falls City shales. Sam Houston has traced this sand from the King's Hills in McMullen County to the eastern part of Gonzales County, where it is covered by the overlap of the Catahoula. It caps the Lipan Hills south of Campbellton. This sandstone is quarried about 3 miles south of Campbellton on the J. Bowers Survey. A railroad switch at this quarry was named Stone's Switch. This name was given by Houston to this quartzitic sandstone, which is massive, indurated sandstone, forming a prominent escarpment. In Atascosa County it is fossiliferous and in Karnes and Gonzales counties much silicified wood occurs. Its thickness ranges from 12 to 20 feet.

Dubose sands and shales.—Stratigraphically above the Stone's Switch sandstones is a series of sands and fossiliferous green and brown

shales with beds of volcanic ash and glass, also beds of ashy, peaty shales. Numerous septaria and cone-in-cone concretions occur. One exceptionally definite fossiliferous boulder horizon is exposed on Sandies Creek, Dubose Ranch, in Gonzales County. At this locality the Catahoula "rice sands" lie unconformably on the Dubose zone. According to Houston's columnar section of the Whitsett (Fig. 3), this zone occurs 300 feet below the top of the Whitsett. The section that Dumble described from the Whitsett bluff on Atascosa River falls within the Dubose zone. The sandstones of Tordilla Hills in western Karnes County are in the Dubose section.

In the upper part of the Dubose zone occurs *Cerithium plicifera* (Heilprin), a gastropod ordinarily opalized which should be an excellent key fossil for field work.

The *Foraminifera* of the Dubose shales include the following species.

FORAMINIFERAL FAUNA OF DUBOSE SHALES

Ammobaculites agglutinans (d'Orbigny)
Anomalina jacksonensis (Cushman and Applin), var. *limbosa* Cushman and Ellisor
Anomalina jacksonensis (Cushman and Applin), var. *texana* (Cushman and Applin)
Elphidium laevis (d'Orbigny), var. *marginatum* Cushman and Ellisor
Nonionella hantkeni (Cushman and Applin)
Valvulineria texana Cushman and Ellisor

Calliham sand.—At the top of the Dubose clays and sands occurs gray fossiliferous sand which is typically exposed on Frio River north of Calliham where the Whitsett-Calliham road crosses the river. Sam Houston, who suggested the name for this sand and who has traced it from Frio River to the Karnes County line, found the sand to vary from highly fossiliferous, fine-grained, gray sand, as found in outcrops on Frio River, to rice-grained and conglomeratic sand, cropping out in Atascosa County south of Campbellton. The sand is approximately 20 feet thick.

Fashing clays.—In the vicinity of Whitsett, Live Oak County, and Fashing, in eastern Atascosa County, occur fossiliferous, bentonitic, green clays weathering to heavy sticky clay. To these clays the name Fashing is given as they are so typically exposed around the town of that name. On the road leading south of Fashing a small creek or gully crosses the road on the S. A. Hickok tract in the J. Hodit Survey. In the bank of this creek is exposed fossiliferous, gray sand, capping olive-green, unctuous clays about 10 feet thick. A very fossiliferous zone of pelecypods occurs in the clays, also a zone of cone-in-cone concretions with a ledge of oysters above. Down the same creek south of Fashing excellent exposures are found.

These clays crop out from Frio River to the western part of Karnes

County. In Live Oak County the rich pelecypod bed crops out on Frio River on the J. T. Brown 42-acre tract in the Michael Hely Survey, also on the S. Hankins and F. W. Tully tracts of the Edward Sorjsham Survey. The Fashing clays are exposed in the vicinity of Whitsett at the type locality of Cushman and Applin's *Nonion whitsettensis* zone. They occur in the upper part of Dumble's Whitsett beds. Exposures also occur in northern Live Oak County on the C. T. Tom Ranch. These clays are 110 feet thick in the vicinity of Whitsett.

FORAMINIFERAL FAUNA OF FASHING CLAYS

Anomalina barrowi Cushman and Ellisor
Anomalina jacksonensis (Cushman and Applin), var. *texana* (Cushman and Applin)
Elphidium eocenicum Cushman and Ellisor
Eponides pygmaea (Hantken)
Nonion whitsettensis (Cushman and Applin)

Olmos sand.—In Atascosa County the top part of the Whitsett consists of grayish brown sandstone as found on Olmos Creek where the Fant City-Whitsett Highway crosses the creek about a mile south of Whitsett.

Bailey[24] also placed the Frio-Jackson contact at this point. He stated:

> The contact between the greenish-gray Frio clay and the brownish-gray, medium-grained Fayette sandstone is exposed at the bridge on the Three Rivers-Whitsett road one mile south of Whitsett.

This sandstone is designated by the writer as the Olmos sand. It has been traced by Sam Houston from Frio River east of Calliham to the Karnes County line. The Olmos sand is a gray, medium-textured sand, weathering brown, about 10–15 feet thick.

WHITSETT OF EASTERN TEXAS

From Fayette County to Trinity County the Whitsett on the surface has not been mapped in detail. In the wells the absence of fossils makes it impossible to determine how much Whitsett and what zones are present. From Trinity County east to Sabine River the Whitsett can not be divided on the basis of lithologic character into the same zones that are found in the western area. John L. Brice traced across Trinity County a fossiliferous zone about 8 feet thick, which crops out at Glendale, Trinity, and south of Groveton, and gave the name Glendale to a section 515 feet thick, including the Manning beds of this paper. Burford and Olcott found the same fossiliferous sandstone and attempted to trace it to Sabine River. Study of their geologic

[24] T. L. Bailey, "The Gueydan, A New Middle Tertiary Formation from the Southwestern Coastal Plain of Texas," *Univ. Texas Bull. 2645* (1926), p. 46.

columns shows that their Glendale sandstone horizon ranges in interval considerably above the Dilworth sand, as shown in section *DD*.

At Mitchell's Ferry on Sabine River on the Texas side is an exposure of very fossiliferous, gray, glauconitic, sandy clay (green when wet). *Massilina pratti* Cushman and Ellisor and *Textularia hockleyensis* Cushman and Applin are found associated in these clays. This is the basal part of the *Massilina pratti* zone of the wells. In Mount Vernon Parish, Louisiana, on the east bank of Bayou Toro in the SE. ¼, NW. ¼ of Sec. 6, T. 3 N., R. 11 W., is a very fossiliferous exposure of the Mitchell's Ferry beds in a bluff 20 feet high. This locality was found by Veatch.[25] This exposure is possibly the upper part of the Mitchell's Ferry beds, which can be traced across Louisiana. In shallow wells in Angelina County the Mitchell's Ferry beds (*Massilina pratti* zone) are 100 feet thick.

The Mitchell's Ferry beds directly overlie the Dilworth sand as far as can be determined from present data. They are possibly the eastern equivalent of the lower part of the Falls City shales. The fauna is plentiful and characteristic.

At the locality on Bayou Toro the following species were found.

FORAMINIFERAL FAUNA OF MITCHELL'S FERRY BEDS

Anomalina bilateralis Cushman
Anomalina jacksonensis (Cushman and Applin), var. *limbosa* Cushman and Ellisor
Anomalina jacksonensis (Cushman and Applin), var. *texana* (Cushman and Applin)
Bolivina gracilis Cushman and Applin
Cibicides lobatulus (Walker and Jacob), var.
Dyocibicides danvillensis Howe and Wallace
Globulina gibba d'Orbigny
Lenticulina rotulata (Lamarck)
Massilina pratti Cushman and Ellisor
Nonion scaphum (Fichtel and Moll), var. *inflatum* Cushman and Ellisor
Nonionella hantkeni (Cushman and Applin)
Nonionella hantkeni (Cushman and Applin), var. *fayettei* Cushman and Ellisor
Planularia ouachitaensis Howe and Wallace
Robulus limbosus (Reuss)
Robulus propinquus (Hantken)
Robulus pseudocultratus Cole
Siphonina carltoni Cushman and Ellisor
Textularia mississippiensis Cushman, var. *alabamensis* Cushman
Triloculina rotunda d'Orbigny
Trochammina teasi Cushman and Ellisor
Uvigerina gardnerae Cushman, var. *texana* Cushman and Applin
Valvulineria texana Cushman and Ellisor
Virgulina dibollensis Cushman and Applin

In the wells the faunal associations vary. The following species have been found.

[25] G. D. Harris and A. C. Veatch, "A Preliminary Report on the Geology of Louisiana," *Louisiana State Exp. Sta., Geol. Agr. La.*, Pt. 5 (1899), p. 90.

FORAMINIFERAL FAUNA OF WHITSETT FORMATION

Ammobaculites agglutinans (d'Orbigny)
Anomalina barrowi Cushman and Ellisor
Anomalina bilateralis Cushman
Anomalina jacksonensis (Cushman and Applin), var. *limbosa* Cushman and Ellisor
Anomalina jacksonensis (Cushman and Applin), var. *texana* (Cushman and Applin)
Bolivina gracilis Cushman and Applin
Bolivina jacksonensis Cushman and Applin
Bolivina tectiformis Cushman
Bulimina jacksonensis Cushman
Bulimina pyrula d'Orbigny
Cassidulina subglobosa H. B. Brady
Cibicides cooperensis Cushman
Cibicides lobatulus (Walker and Jacob), var.
Cornuspira involvens (Reuss)
Dyocibicides danvillensis Howe and Wallace
Elphidium eocenicum Cushman and Ellisor
Epistomina elegans (d'Orbigny)
Eponides pygmaea (Hantken)
Glandulina radicula (Linné)
Globigerina bulloides d'Orbigny
Globorotalia cocoaensis Cushman
Globulina gibba d'Orbigny
Hantkenina alabamensis Cushman
Lenticulina rotulata (Lamarck)
Marginulina cocoaensis Cushman
Massilina humblei Cushman and Ellisor
Massilina pratti Cushman and Ellisor
Nodosaria cocoaensis Cushman
Nonion inexcavatum (Cushman and Applin), var.
Nonion laevis (d'Orbigny), var. *marginatum* Cushman and Ellisor
Nonion scaphum (Fichtel and Moll), var. *inflatum* Cushman and Ellisor
Nonion whitsettensis (Cushman and Applin)
Nonionella hantkeni (Cushman and Applin)
Nonionella hantkeni (Cushman and Applin), var. *fayettei* Cushman and Ellisor
Planularia ouachitaensis Howe and Wallace
Plectofrondicularia mexicana (Cushman)
Pyrgo inornata (d'Orbigny), var. *danvillensis* Howe and Wallace
Quinqueloculina hauerina d'Orbigny
Quinqueloculina seminula (Linné)
Robulus gutticostatus (Gümbel), var. *cocoaensis* Cushman
Robulus limbosus (Reuss)
Robulus propinquus (Hantken)
Robulus pseudocultratus Cole
Saracenaria italica Defrance
Siphonina carltoni Cushman and Ellisor
Sphaeroidinella dehiscens (Parker and Jones)
Textularia adalta Cushman
Textularia hockleyensis Cushman and Applin
Textularia mayeriana d'Orbigny
Textularia mississippiensis Cushman, var. *alabamensis* Cushman
Textularia [*Spiroplectammina*] *carinata* d'Orbigny
Triloculina rotunda d'Orbigny yar.
Trochammina teasi Cushman and Ellisor
Tubulogerina eocenica Cushman and Ellisor
Uvigerina alata Cushman and Applin
Uvigerina cocoaensis Cushman
Uvigerina gardnerae Cushman, var. *texana* Cushman and Applin
Uvigerina jacksonensis Cushman
Valvulineria texana Cushman and Ellisor
Virgulina dibollensis Cushman and Applin

CHECK LIST OF JACKSON SPECIES

	Whitsett	*McElroy*	*Caddell*
Ammobaculites agglutinans (d'Orbigny)	x		x
Ammobaculites hockleyensis Cushman and Applin		x	x
Anomalina barrowi Cushman and Ellisor	x		
Anomalina bilateralis Cushman	x	x	x
Anomalina jacksonensis (Cushman and Applin)		x	x
Anomalina jacksonensis (Cushman and Applin), var. *limbosa* Cushman and Ellisor	x		
Anomalina jacksonensis (Cushman and Applin), var. *texana* (Cushman and Applin)	x	x	x
Bathysiphon filiformis M. Sars		x	x
Bolivina beyrichi Reuss, var. *carinata* Hantken		x	
Bolivina gracilis Cushman and Applin	x	x	x
Bolivina jacksonensis Cushman and Applin	x	x	x
Bolivina tectiformis Cushman	x		
Bulimina jacksonensis Cushman	x	x	x
Bulimina pyrula d'Orbigny	x	x	x
Buliminella alabamensis Cushman		x	
Buliminella elegantissima (d'Orbigny)		x	
Buliminella subfusiformis Cushman		x	x
Cassidulina subglobosa H. B. Brady	x		x
Cibicides cooperensis Cushman	x		
Cibicides cf. *ungerianus* (d'Orbigny)			x
Cibicides lobatulus (Walker and Jacob) var.	x		
Cibicides lobatulus (Walker and Jacob)		x	x
Cibicides yazooensis Cushman		x	x
Cornuspira involvens (Reuss)	x		
Dentalina cf. *cocoaensis* Cushman			x
Dentalina cocoaensis Cushman		x	
Dentalina jacksonensis Cushman		x	
Dentalina pauperata d'Orbigny			x
Discorbis farishi Cushman and Ellisor		x	
Discorbis hemisphaerica Cushman			x
Dyocibicides danvillensis Howe and Wallace	x		
Elphidium eocenicum Cushman and Ellisor	x		
Epistomina elegans (d'Orbigny)	x		
Eponides jacksonensis (Cushman and Applin)		x	x
Eponides pygmaea (Hantken)	x		
Gaudryina advena Cushman			x
Glandulina laevigata (d'Orbigny)			x
Glandulina laevigata (d'Orbigny), var. *ovata* (Cushman and Applin)			x
Glandulina radicula (Linné)	x		
Globigerina bulloides d'Orbigny	x	x	x
Globorotalia cocoaensis Cushman	x		x
Globulina gibba d'Orbigny	x	x	
Guttulina hantkeni Cushman and Ozawa			x
Guttulina irregularis (d'Orbigny)		x	x
Guttulina problema d'Orbigny		x	x
Guttulina spicaeformis (Roemer)		x	
Hantkenina alabamensis Cushman	x	x	x
Haplophragmoides dibollensis Cushman and Applin		x	x
Lagena cf. *striata* d'Orbigny			x
Lamarckina ocalana Cushman			x
Lenticulina rotulata (Lamarck)	x		
Marginulina cocoaensis Cushman	x		
Marginulina fragaria (Gümbel), var. *texasensis* (Cushman and Applin)		x	x
Marginulina glabra (d'Orbigny)			x

CHECK LIST OF JACKSON SPECIES (*Continued*)

	Whitsett	*McElroy*	*Caddell*
Marginulina jacksonensis (Cushman and Applin)		x	x
Marginulina pediformis Bornemann		x	
Massilina decorata Cushman		x	
Massilina humblei Cushman and Ellisor	x	x	
Massilina pratti Cushman and Ellisor	x		
Nodosaria cocoaensis Cushman	x		
Nodosaria jacksonensis Cushman and Applin		x	x
Nodosaria spinescens (Reuss)			x
Nodosaria vertebralis (Batsch)		x	
Nodosaria vertebralis (Batsch) H. B. Brady			x
Nonion chapapotensis Cole		x	
Nonion inexcavatum (Cushman and Applin), var.	x		
Nonion inexcavatum (Cushman and Applin)		x	x
Nonion laevis (d'Orbigny), var. *marginatum* Cushman and Ellisor	x		
Nonion micrus Cole		x	x
Nonion scaphum (Fichtel and Moll), var. *inflatum* Cushman and Ellisor	x		
Nonion umbilicatulum (Montagu)			x
Nonion whitsettensis (Cushman and Applin)	x	x	
Nonionella hantkeni (Cushman and Applin)	x	x	
Nonionella hantkeni (Cushman and Applin), var. *fayettei* Cushman and Ellisor	x		
Nonionella hantkeni (Cushman and Applin), var. *spissa* Cushman			x
Operculina oliveri Cushman			x
Planularia cf. *wuellerstorfi* (Schwager)			x
Planularia ouachitaensis Howe and Wallace	x		
Plectofrondicularia mexicana (Cushman)	x		x
Pseudopolymorphina dumblei (Cushman and Applin)		x	
Pyrgo inornata (d'Orbigny), var. *danvillensis* Howe and Wallace	x		
Quinqueloculina hauerina d'Orbigny	x		
Quinqueloculina seminula (Linné)	x	x	
Robulus alato-limbatus (Gümbel)		x	x
Robulus articulatus (Reuss), var. *texanus* (Cushman and Applin)		x	x
Robulus cf. *alato-limbatus* (Gümbel)			x
Robulus cultratus Montfort		x	x
Robulus gutticostatus (Gümbel), var. *cocoaensis* Cushman	x		
Robulus limbosus (Reuss)	x		
Robulus limbosus (Reuss), var. *hockleyensis* Cushman and Applin		x	
Robulus propinquus (Hantken)	x		x
Robulus pseudocultratus Cole	x		
Saracenaria italica (Defrance)	x		x
Sigmomorphina jacksonensis (Cushman)		x	x
Sigmomorphina jacksonensis (Cushman), var. *costifera* (Cushman)			x
Siphonina advena Cushman, var. *eocenica* Cushman and Applin		x	x
Siphonina carltoni Cushman and Ellisor	x		
Siphonina jacksonensis Cushman and Applin			x
Sphaeroidinella dehiscens (Parker and Jones)	x		
Textularia adalta Cushman	x		
Textularia carinata d'Orbigny		x	
Textularia cf. *mexicana* Cushman			x
Textularia dibollensis Cushman and Applin			x

CHECK LIST OF JACKSON SPECIES (*Continued*)

	Whitsett	*McElroy*	*Caddell*
Textularia hockleyensis Cushman and Applin	x	x	
Textularia mayeriana d'Orbigny	x		
Textularia mississippiensis Cushman, var. *alabamensis* Cushman	x		x
Textularia mississippiensis Cushman		x	x
Textularia mississippiensis Cushman, var. *rhomboidea* Cushman and Ellisor			x
Textularia [*Spiroplectammina*] *carinata* d'Orbigny	x		
Triloculina rotunda d'Orbigny, var.	x		
Trochammina teasi Cushman and Ellisor	x		
Tubulogerina eocenica Cushman and Ellisor	x		x
Uvigerina alata Cushman and Applin	x	x	x
Uvigerina cocoaensis Cushman	x	x	
Uvigerina gardnerae Cushman, var. *texana* Cushman and Applin	x	x	x
Uvigerina jacksonensis Cushman	x		
Uvigerina pygmaea d'Orbigny		x	x
Uvigerina topilensis Cushman			x
Valvulineria texana Cushman and Ellisor	x		
Virgulina dibollensis Cushman and Applin	x		x

VICKSBURG FORMATION

The Vicksburg formation in wells was first definitely recognized in Texas by the writer in January, 1927, when the joint test of the Humble Oil and Refining Company and the Rycade Oil Corporation Kountz No. 3 was drilled on the Markham dome in Matagorda County. The Vicksburg fauna was encountered from 3,420 to 3,636 feet. Sixty species were found, fifty-seven of which are present in the Vicksburg of Mississippi.

Angulogerina byramensis (Cushman)
Anomalina bilateralis Cushman
Anomalina mississippiensis
Articulina byramensis Cushman
Asterigerina bracteata Cushman
Asterigerina subacuta Cushman
Bifarina vicksburgensis (Cushman)
Bolivina caelata Cushman
Bolivina cookei Cushman
Bolivinella subpectinata (Cushman)
Bulimina ovata d'Orbigny
Bulimina pupoides d'Orbigny
Bulimina sculptilis Cushman
Cassidulina crassa d'Orbigny
Cibicides americanus (Cushman)
Cibicides floridanus (Cushman)
Cibicides lobatulus (Walker and Jacob) (d'Orbigny)
Cibicides mississippiensis (Cushman)
Cibicides pseudoungerianus (Cushman)
Cornuspira involvens Reuss
Discorbis byramensis Cushman
Discorbis orbicularis (Terquem, non d'Orbigny
Elphidium poeyanum (d'Orbigny)

Eponides byramensis (Cushman)
Eponides vicksburgensis Cushman and Ellisor
Globigerina bulloides d'Orbigny
Globigerina dutertrei d'Orbigny
Globulina gibba d'Orbigny
Guttulina problema d'Orbigny
Haplophragmoides cf. *dibollensis* Cushman and Applin
Lagena laevigata (Reuss)
Lagena striata (d'Orbigny) , var. *substriata* Williamson
Lenticulina rotulata (Lamarck)
Loxostoma amygdalaeforme (H. B. Brady), var. *delicatum* Cushman
Loxostoma hiwaneense Howe
Massilina decorata Cushman
Nodosaria catenulata H. B. Brady
Nonion advenum (Cushman)
Nonion scaphum (Fichtel and Moll) (Parker and Jones)
Nonion umbilicatulum (Montagu)
Nonionella tatumi Howe
Quinqueloculina bicostata d'Orbigny
Reussia spinulosa Reuss, var. *glabrata* Cushman
Robulus alato-limbatus Gümbel
Robulus convergens (Bornemann)
Robulus cultratus (Montfort)
Robulus vicksburgensis (Cushman)
Rotalia dentata Parker and Jones, var. *parva* Cushman
Saracenaria italica Defrance
Siphonina advena Cushman
Siphogenerina irregularis (Bagg) Cushman
Textularia mississippiensis Cushman
Textularia tumidula Cushman
Textularia warreni Cushman and Ellisor
Uvigerina byramensis Cushman
Uvigerina vicksburgensis Cushman and Ellisor
Virgulina cf. *dibollensis* Cushman and Applin

Later the same fauna was found at Goose Creek, Harris County, Texas, in the Humble Oil and Refining Company wells drilled on the Simms Smith tract. This fauna was found below a series of green clays and sands lithologically like the Frio. As a few Lower Oligocene species, *Eponides vicksburgensis* Cushman and Ellisor, *Elphidium poeyanum* (d'Orbigny), *Nonionella tatumi* Howe, and *Textularia warreni* Cushman and Ellisor were found in the basal part of these clays, the age is regarded as Lower Oligocene, especially as they occur below the Middle Oligocene, that is, below the *Marginulina* zone of the Middle Oligocene. These clays in the wells can be traced into the Frio on the surface.

The Humble Oil and Refining Company's Simms Smith, No. 73, which furnishes a type section of the Lower Oligocene in this area, has 950 feet of green noncalcareous shale containing calcareous nodules and lenses of greenish gray sand below the Middle Oligocene (*Marginulina* zone). In the lower part of the section *Eponides vicksburgensis* Cushman and Ellisor, *Elphidium poeyanum* (d'Orbigny), and *Nonionella tatumi* Howe occur. These clays are classified as the Frio.

At 5,400 feet the lithologic character changes to brown, calcareous shale containing a plentiful fauna, including the following typical Vicksburg species, all of which occur in the Byram marl.

Angulogerina byramensis (Cushman)
Anomalina bilateralis Cushman
Anomalina mississippiensis Cushman
Asterigerina subacuta Cushman
Bifarina Vicksburgensis (Cushman)
Bolivina alazanensis Cushman
Bolivina caelata Cushman
Bolivina cookei Cushman
Bolivinella subpectinata (Cushman)
Bulimina ovata d'Orbigny
Bulimina pupoides d'Orbigny
Bulimina pyrula d'Orbigny
Bulimina sculptilis Cushman
Cassidulina crassa d'Orbigny
Cibicides americanus (Cushman)
Cibicides floridanus (Cushman)
Cibicides pseudoungerianus (Cushman)
Cornuspira involvens Reuss
Discorbis byramensis Cushman
Discorbis orbicularis (Terquem, non d'Orbigny)
Eponides byramensis (Cushman)
Eponides vicksburgensis Cushman and Ellisor
Globigerina apertura Cushman
Globigerina bulloides d'Orbigny
Globigerina dutertrei d'Orbigny
Globulina amygdaloides (Reuss)
Globulina gibba d'Orbigny
Globulina spinosa (d'Orbigny)
Guttulina irregularis (d'Orbigny)
Guttulina problema (d'Orbigny)
Haplophragmoides cf. *dibollensis* Cushman and Applin
Lenticulina rotulata (Lamarck)
Loxostoma amygdalaeforme (H. B. Brady), var. *delicatum* Cushman
Loxostoma hiwaneense Howe
Massilina crusta Cushman
Massilina decorata Cushman
Nodosaria catenulata H. B. Brady
Nodosaria cf. *jacksonensis* Cushman and Applin
Nonion advenum (Cushman)
Nonion scaphum (Fichtel and Moll) (Parker and Jones)
Nonion umbilicatulum (Montagu)
Nonionella tatumi Howe
Quinqueloculina bicostata d'Orbigny
Reussia spinulosa Reuss, var. *glabrata* Cushman
Rotalia dentata Parker and Jones, var. *parva* Cushman
Robulus convergens Bornemann
Robulus cultratus (Montfort)
Robulus vicksburgensis (Cushman)
Saracenaria italica Defrance
Siphogenarina irregularis (Bagg)
Siphonina advena Cushman
Textularia mississippiensis Cushman
Textularia tumidula Cushman
Textularia warreni Cushman and Ellisor
Uvigerina byramensis Cushman
Uvigerina vicksburgensis Cushman and Ellisor
Virgulina cf. *dibollensis* Cushman and Applin

At 6,171 feet there is another change in character to greenish gray shale and sandy shale. There is much sand in this part of the section. The following species which occur in the Red Bluff characterize these beds.

Anomalina bilateralis Cushman
Anomalina mississippiensis Cushman
Bathysiphon filiformis M. Sars
Bifarina vicksburgensis (Cushman)
Bolivina alazanensis Cushman
Bulimina pupoides d'Orbigny
Bulimina sculptilis Cushman
Cassidulina crassa d'Orbigny
Cibicides mississippiensis
Cibicides pseudoungerianus (Cushman)
Clavulina byramensis Cushman, var. *extans* Cushman
Eponides byramensis (Cushman)
Gaudryina advena Cushman
Globigerina bulloides d'Orbigny
Globigerina dutertrei d'Orbigny
Globulina gibba d'Orbigny
Globulina rotundata (Bornemann)
Globulina spinosa (d'Orbigny)
Guttulina irregularis (d'Orbigny)
Guttulina problema (d'Orbigny)
Gyroidina vicksburgensis (Cushman)
Marginulina glabra d'Orbigny
Marginulina pediformis Bornemann
Nodosaria ewaldi Reuss
Nodosaria vertebralis (Batsch)
Robulus cf. *limbatus* (Bornemann)
Robulus convergens (Bornemann)
Robulus integrus (Bornemann)
Robulus iotus Cushman
Robulus vicksburgensis (Cushman)
Saracenaria italica Defrance
Spiroloculina antillarum d'Orbigny
Textularia carinata d'Orbigny
Textularia cf. *porrecta* H. B. Brady
Textularia mississippiensis Cushman
Textularia warreni Cushman and Ellisor

There are also present several species that occur in the Red Bluff faunule, but which are not described as follows.

Cibicides sp.
Eponides (two species)
Nodosaria sp.
Robulus (two species)
Siphonina (two species)
Uvigerina sp.

In the area south of Houston, at Goose Creek, Mykawa, West Columbia, Damon Mound, and Markham, species occur which characterize the Byram marl, and below these occur species that characterize the Red Bluff. In the wells drilled toward the outcrops as far north as Raccoon Bend, the Red Bluff is the phase present. The

Vicksburg sea in Texas was, therefore, a retreating sea, having deposited its basal beds farthest inland.

There is no paleontological evidence of the Vicksburg on the surface in Texas, although it is known to occur in Mexico a few miles below the Rio Grande. In East Texas, wells very near the outcrop encounter the Vicksburg at a shallow depth. There is a possibility that some day fossiliferous outcrops of the Vicksburg will be found in Texas.

FRIO FORMATION

The Frio formation was originally named by Dumble[26] in 1894 for Frio River in southwestern Texas. Dumble,[27] in 1924, after giving the Fayette section, described the Frio as follows.

The Frio marks a change from a formation that is characteristically sandy to one that is mostly clay. The lowest beds which can with certainty be referred to the Frio in the Atascosa section were found on the river southwest of Fant City, a short distance above the mouth of Weedy Creek. A yellow, massive, calcareous sand with bands of hardened light green sand was here overlain by green, waxy clays with thin streaks of gypsum, rusty streaks and cherty concretions. These clays weather white and are for the most part non-calcareous. Highly characteristic exposures of these beds occur up Weedy Creek for several miles. Similar beds continue down the river, some of the clays being bright green or blue-green when fresh, but all weather white and resemble caliche when exposed. Nearing the middle of the section the green, waxy clays and greenish sands carry bands of calcareous concretions. The upper beds are light green clays and sandy clays with calcareous concretions distributed through them irregularly for the most part but sometimes in lines. Some beds of brown sand occur. The final exposure of the Frio is found just south of the sharp bend in the Nueces where it changes from its northeast to its southerly course.

Deussen[28] in 1924 described the Frio as follows.

The Frio includes green and pink clay that contains small nodules of lime; green, sandy, calcareous clay, and beds of light green marl consisting of lime and kaolinitic material with pisolitic structure. South of Atascosa Creek the lower beds include layers of brown, fossiliferous marl of marine origin, beds of gray sandstone, and in places concretions from 4 inches to 3 feet in diameter, of hard, compact, green, siliceous limestone stained with manganese. Fragments of agatized wood, beds of volcanic ash, and nodules and masses of white chalcedony may also be seen in places.

[26] E. T. Dumble, "The Cenozoic Deposits of Texas," *Jour. Geol.*, Vol. 2 (1894), pp. 554–55.

[27] E. T. Dumble, "A Revision of the Texas Tertiary Section with Special Reference to the Oil-Well Geology of the Coast Region," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 4 (July–August, 1924), pp. 424–44.

[28] Alexander Deussen, "Geology of the Coastal Plain of Texas West of Brazos River," *U. S. Geol. Survey Prof. Paper 126* (1924), p. 92.

Deussen stated that the Frio lies conformably above the Fayette west of Colorado River and that west of the Brazos the Frio lies conformably beneath the Catahoula, but farther west it lies unconformably beneath the Oakville sandstones.

Bailey,[29] in 1926, redefined the Frio and limited it to the lower part of Deussen's section or that part which is principally clay. The upper division he defined as Gueydan and correlated with the Catahoula. He stated that his redefined Frio is probably of Eocene age.

Due to lack of fossils in the Frio clays on the surface, the age has not been established heretofore. The well data supply the evidence to prove the age and stratigraphic position of the Frio clays. The name Frio is here used to designate those clays which occur in the wells between the Middle Oligocene[30] and the Vicksburg, therefore are of Oligocene age. These clays occur on the surface unconformably below the Catahoula "rice sands" or Soledad, and rest unconformably on the Whitsett. The Frio of this paper includes the Fant member of Bailey's[31] Gueydan and his Frio. In the wells there is no lithologic difference in the character of the Frio and the Fant. Therefore, it is impossible to differentiate the two. On the surface they occur as two mappable units.

The Frio formation consists of green and purple bentonitic clays, containing calcareous nodules, pyrite, and in places volcanic glass. Lenses of sand are present which consist largely of milky or translucent quartz. A scant fauna is found in the wells. The fauna includes the following.

Ammobaculites agglutinans (d'Orbigny)
Chara seed
Elphidium sp.
Eponides vicksburgensis Cushman and Ellisor
Ostracods
Rotalia beccarii var.

With the data available at present, the writer is placing the Catahoula "rice sands," or the Soledad, their stratigraphic equivalent,

[29] T. L. Bailey, "The Gueydan, A New Middle Tertiary Formation from the Southwestern Coastal Plain of Texas," *Univ. Texas Bull. 2645* (1926).

[30] The beds here designated as Middle Oligocene in age were identified as Middle Oligocene in age by Cushman in 1922 in an unpublished report to the Humble Oil and Refining Company. They are characterized by *Heterostegina antillea*, the key fossil of the Antigua formation, which was determined by Vaughan as the type of the American Middle Oligocene in his paper on the "Geology and Paleontology of the Canal Zone," *U. S. Nat. Museum Bull. 103* (1919), p. 202. The micro-fauna of our Middle Oligocene beds is more closely allied to the Vicksburg than to any known Miocene of the Coastal Plain. There is a desire on the part of some workers to place the Antigua formation and the Texas Middle Oligocene beds in the Miocene. Regardless of whether our Middle Oligocene beds are later shown to be Miocene, the fact remains that they are stratigraphically older than any known Miocene of the Gulf Coast.

[31] T. L. Bailey, *op. cit.*, p. 66.

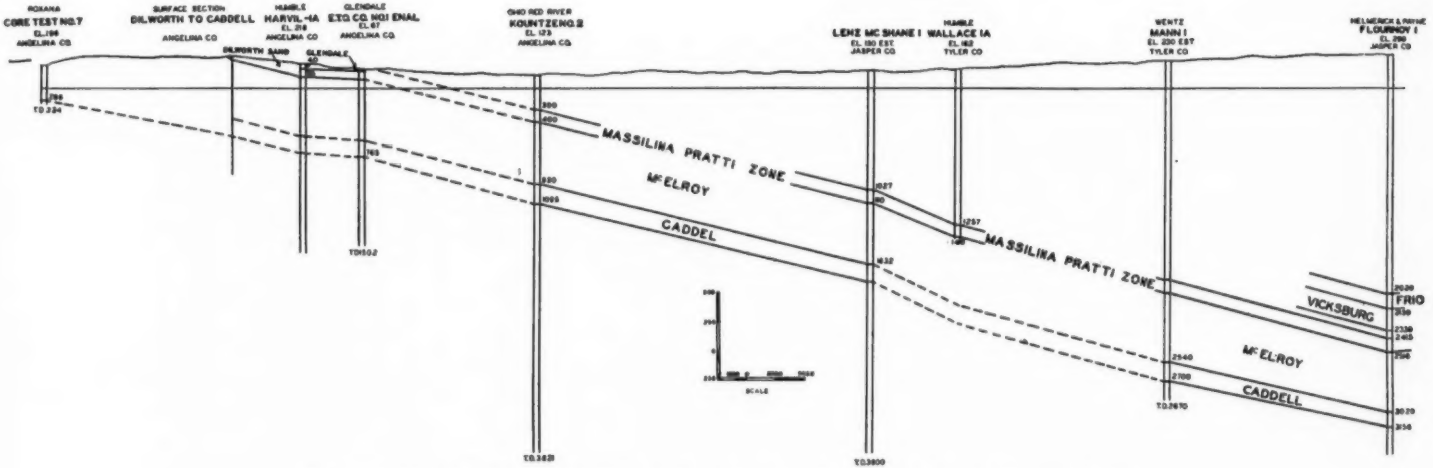

FIG. 4.—Section *AA*, showing *Massilina pratti* zone from Angelina County to Jasper County, Texas.

below the Middle Oligocene. These sands apparently become a part of the Frio as found in the wells.

SECTIONS

Section AA.—In Louisiana the surface section of the Jackson is the same as the subsurface section. As shown in section *EE*, the *Massilina pratti* zone is a better horizon for contouring purposes than the first appearance of *Textularia hockleyensis*, which varies in its range in the geologic column. The *Massilina pratti* zone, which is equivalent to the Mitchell's Ferry beds, has not been found on the surface west of Sabine River, but has been found in Humble core tests in Angelina County. Outcrops should be found as a result of detailed field work.

In an attempt to correlate the surface section with that in the wells, section *AA* was drawn from the outcrop of the Caddell in Angelina County to Helmerick and Payne's Flournoy No. 1 in Jasper County.

In Flournoy No. 1 from 2,020 to 2,150 feet, a few Vicksburg *Foraminifera* are present, particularly *Eponides vicksburgensis* Cushman and Ellisor, and *Elphidium poeyanum* (d'Orbigny). This zone is possibly the equivalent of those beds in East Texas between the Chita sand and the first fossiliferous zone and is either Frio or Vicksburg in age.

From 2,330–2,347 feet occurs a fossiliferous horizon. The megascopic fossils present were identified for the writer by Julia Gardner as Vicksburg in age. The following were present.

Acteocina crassiplica (Conrad)
Olivella sp. ind. (possibly young of *Olivella affluens* Casey)
Ringicula mississippiensis Conrad
Spisula funerata (Conrad)
Terebra cf. *tantula* Conrad

From 2,347 to 2,415 feet the samples are cuttings. Only Vicksburg fossils were noted. The first evidence of Jackson was the *Massilina pratti* fauna at 2,415 feet. This zone is 100 feet thick in this well. It also occurs in the Humble's Wallace No. 1-A from 1,257 to 1,400 feet; in Lenz' McShane No. 1 from 1,027 to 1,110 feet; and in Ohio-Red River's Kountze No. 2 from 300 to 400 feet. This horizon projected to the surface includes the Dilworth sand and the Glendale zone.

With present information the Dilworth sand seems to be approximately at the base of the Whitsett formation.

Section BB.—Section *BB* (Fig. 5), which is a section from Schulenburg in Fayette County to Goose Creek in Harris County, shows the wedging-in of the Middle Oligiocene formation and of the Vicksburg

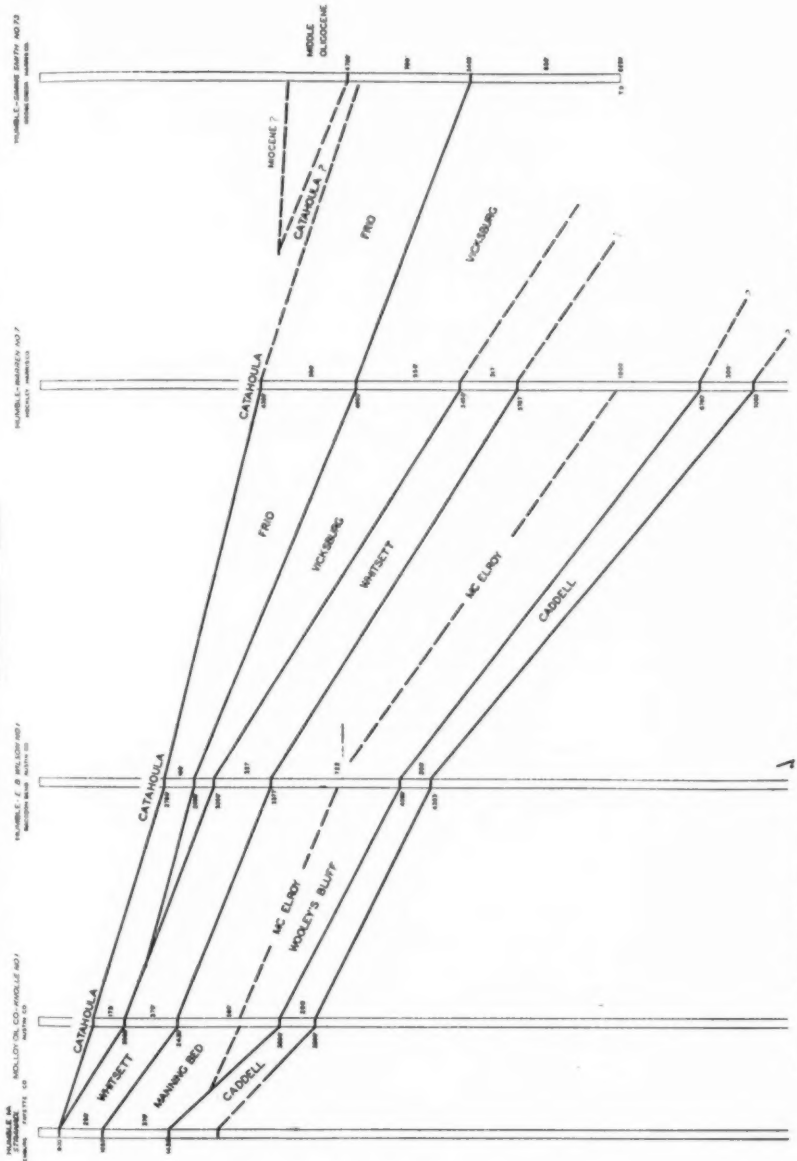

FIG. 5.—Section *BB*. Diagrammatic section from Schulenburg, Fayette County, to Goose Creek, Harris County, showing Oligocene and Jackson formations.

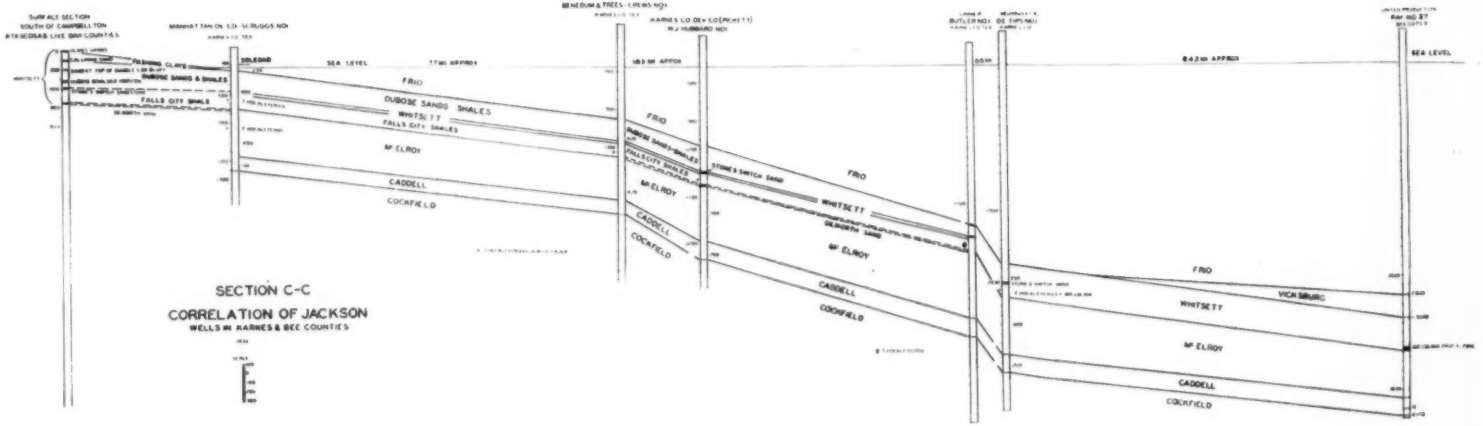
SECTION C-C
CORRELATION OF JACKSON
WELLS IN KARNES & BEE COUNTIES
SOLEDAD
SEA LEVEL
FRIO
DUBOSE SANDS
SHALES
WHITSETT
FALLS CITY SHALES
MF ELROY
CADDELL
COCKFIELD
STONES SWITCH SAND
VICKSBURG

FIG. 6

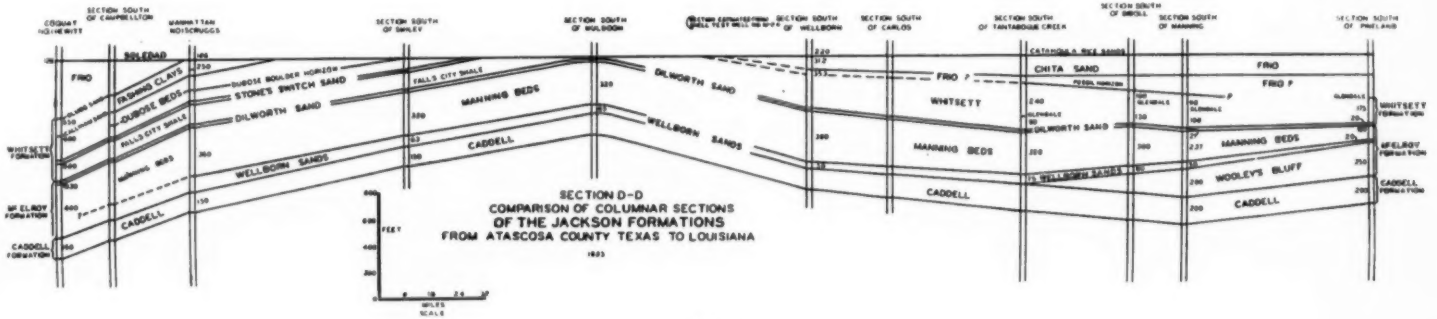
SECTION D-D
COMPARISON OF COLUMNAR SECTIONS
OF THE JACKSON FORMATIONS
FROM ATASCOSA COUNTY TEXAS TO LOUISIANA
SOLEDAD
FRIO
FISHING CLAYS
DUBOSE BEDS
DUBOSE BOULDER HORIZON
STONES SWITCH SAND
DILWORTH SAND
WELLBORN SANDS
CADDELL
WHITSETT FORMATION
MF ELROY FORMATION
CADDELL FORMATION
FALLS CITY SHALE
MANNING BEDS
WHITSETT
CHITA SAND
WOOLEY'S BLUFF
FEET
MILES
SCALE

FIG. 7

formation, which are completely overlapped down the dip from the surface.

At Goose Creek the Oligocene section is complete and shows the three zones of the Middle Oligocene, the Frio, and the Vicksburg. Above the Middle Oligocene there are no sands here which are lithologically comparable with the Catahoula "rice sands." However, there are sands in the Frio which are comparable with the Catahoula. The drill did not penetrate the Jackson.

At Hockley the Middle Oligocene is absent, the Middle Oligocene sea not having encroached so far inland, or if it did, erosion has since removed its deposits. The Vicksburg is considerably thinner, the fossils indicating that the beds present are the same as the lower phase at Goose Creek. The Whitsett has approximately its normal thickness and the McElroy has its thickest known section. Likewise the Caddell is thicker than normal. This thickening may be only apparent, since the beds probably dip steeply on the dome.

At Raccoon Bend both the Frio and Vicksburg are present, both becoming considerably thinner toward the outcrop. The Vicksburg has thinned from 550 to 50 feet and disappears north of Raccoon Bend. Wells at Schulenburg have the same section as found on the surface in western Fayette County and Gonzales County. This section shows the Frio as well as the Vicksburg overlapped, the Catahoula sands resting unconformably on the Whitsett (Fayette) of the Jackson group.

FIG. 7

Section CC.—In Karnes County, *Textularia hockleyensis* Cushman and Applin is associated with a few Whitsett species in the Falls City shales. Section *CC* is given to show that the Falls City shales in the wells down dip occur above the McElroy and include the *Massilina pratti* zone.

In the United Production Company's Ray No. 37 in Bee County the Caddell occurs from 3,881 to 4,073 feet, above which there are 500 feet of McElroy. The Whitsett-McElroy contact is placed at the base of the *Massilina pratti* zone at 3,384 feet. There are 344 feet of Whitsett, which lies unconformably below the Vicksburg. Eight miles up the dip from this well in the Neuhaus *et al.* D. E. Tips No. 1 the formations thicken. The Caddell is 200 feet thick, the McElroy 600 feet thick, and the Whitsett 350 feet thick. *Massilina pratti* occurs at 2,750 feet, associated with *Textularia hockleyensis*. Whitsett species present are the following.

Anomalina jacksonensis var. *limbosa*
Nonionella hantkeni var. *fayettei*
Nonion laevis var. *marginatum*
Trochammina teasi
Valvulineria texana

Above this fauna occurs a sandstone that can be traced up the dip in the wells just above a brown shale, in which *Textularia hockleyensis* and a few Whitsett species occur. This sand can be traced into the Stone's Switch sand, which lies in contact with the Falls City shales. In this area *Textularia hockleyensis* in the wells occurs at a rather constant interval below the top of the sandstone, approximately from 80 to 100 feet, as shown in the section. In this part of the state the first appearance of *Textularia hockleyensis* does not indicate the top of the McElroy. However, *Textularia hockleyensis* may be used for correlation purposes in Karnes, Bee, Live Oak, Fayette, and Gonzales counties.

On comparing the surface section of the Whitsett from the type locality with the wells in this area it is noted that the thinning of the Whitsett down dip is due to an unconformity east of Atascosa and Live Oak counties, the top of the Whitsett (formerly Fayette) being the Dubose beds, the Fashing beds being absent.

Section DD.—As stated before, there is an unconformity in the wells at the top of the Jackson. On the surface, in addition to the unconformity at the top of the Whitsett, east of Karnes County there is a progressive overlap of the Jackson by the Catahoula "rice sands" so that in the area between eastern Fayette County and Brazos County the Whitsett formation does not crop out.

Detailed sections have been made of the Jackson in nearly every county. Section *DD* shows the variations in the Jackson beds across the state.

Olcott and Burford measured the sections from Trinity County east to Sabine River. The section south of Muldoon, Fayette County, was measured by Burford. The sections from Gonzales County to Atascosa County are based on the work of Sam Houston on the Whitsett, and on that of H. D. McCallum on the basal Jackson.

This section shows that the Caddell extends across the entire area with a uniform thickness. Above the Caddell occurs the Wooley's Bluff zone of the McElroy east of Trinity County. West of Trinity County the Wooley's Bluff is overlapped by the Wellborn, not only on the surface, but for some distance down the dip from the surface.

The Wellborn sands were deposited under marine conditions across the entire area. With the withdrawal of the Wellborn sea came a period of nonmarine deposition with an occasional invasion of the sea. Thick beds of volcanic material were laid down, some of them under water, as shown by the cross-bedded sands of volcanic glass. These beds of uniform lithologic character were deposited across the entire area. They are the Manning beds.

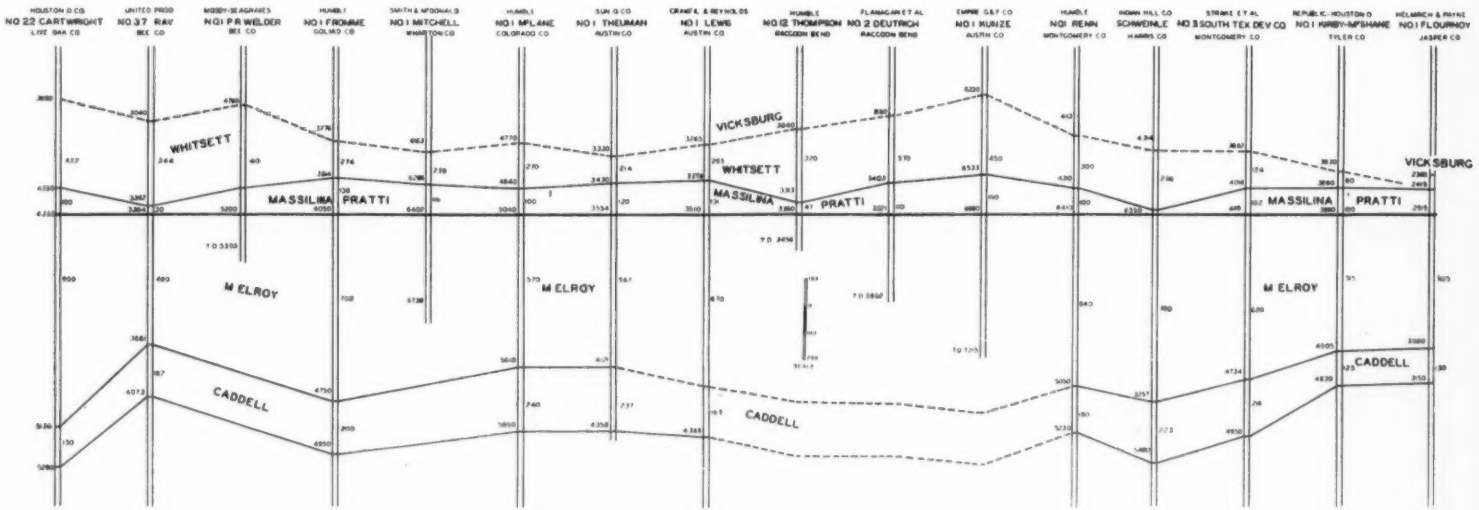

FIG. 8.—Section *EE*, Live Oak County to Jasper County.

The following seven plates show characteristic *Foraminifera* of the Vicksburg and Jackson formations.

EXPLANATION OF PLATE 1

FIGS. 1 *a*, *b*.—*Textularia warreni* Cushman and Ellisor. ×50.
a, front view; *b*, apertural view.
FIGS. 2 *a*, *b*.—*Textularia mississippiensis* Cushman, var. *rhomboidea* Cushman and Ellisor. ×60.
a, front view; *b*, apertural view.
FIG. 3.—*Textularia tumidula* Cushman. ×50.
FIG. 4.—*Textularia dibollensis* Cushman and Applin. ×60.
FIG. 5.—*Textularia mayeriana* d'Orbigny. ×60.
FIG. 6.—*Textularia mississippiensis* Cushman, var. *alabamensis* Cushman. ×60.
FIG. 7.—*Textularia hockleyensis* Cushman and Applin. ×50.
FIG. 8.—*Clavulina byramensis* Cushman, var. *extans* Cushman. ×40.
FIGS. 9 *a–c*.—*Trochammina teasi* Cushman and Ellisor. ×90.
a, dorsal view; *b*, ventral view; *c*, peripheral view.
FIGS. 10 *a–c*.—*Massilina pratti* Cushman and Ellisor. ×60.
a, *b*, opposite sides; *c*, apertual view.
FIGS. 11 *a*, *b*.—*Robulus limbosus* (Reuss), var. *hockleyensis* (Cushman and Applin). ×60.
a, side view; *b*, peripheral view.

Figures drawn by Margaret S. Moore

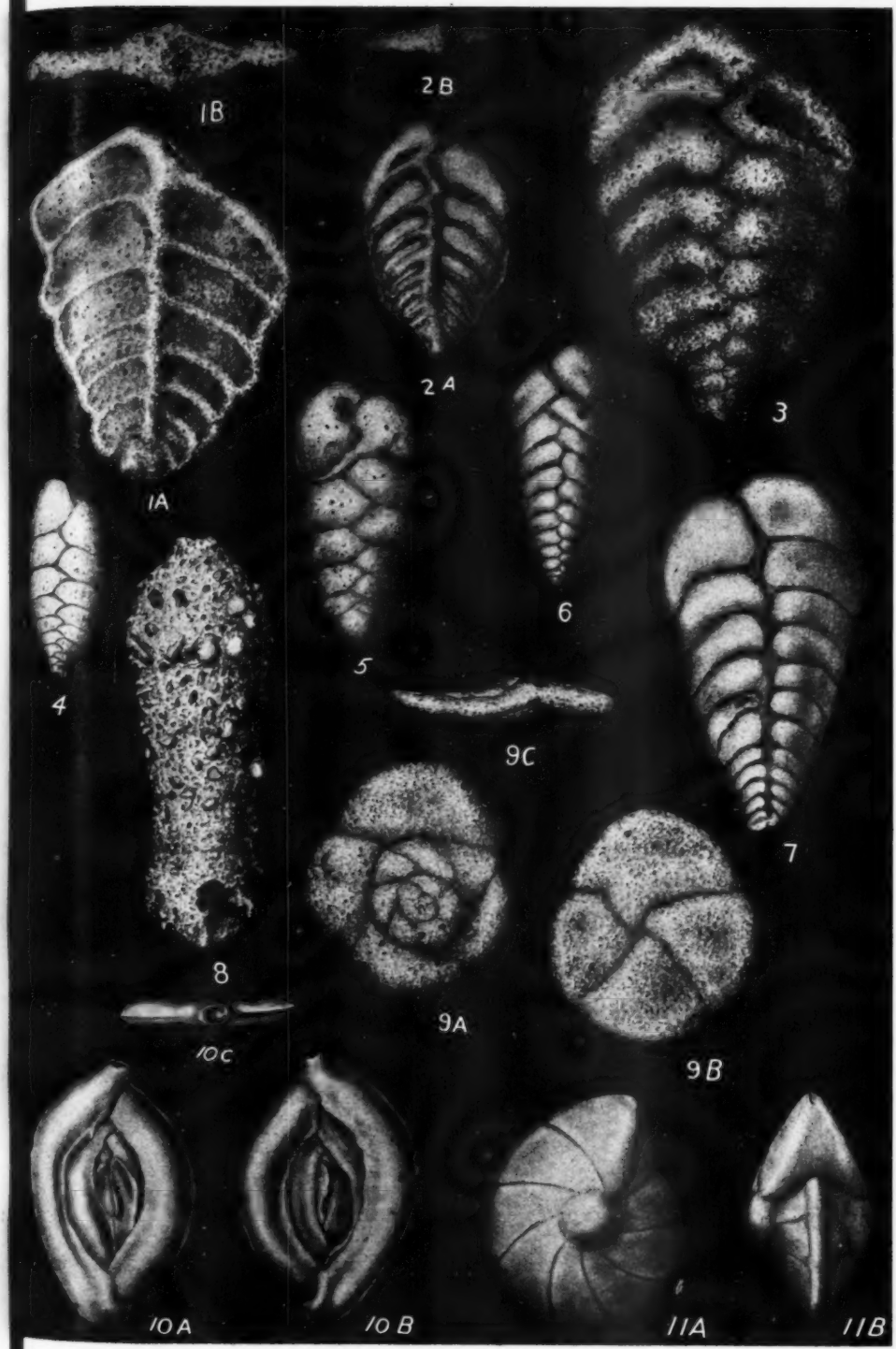

PLATE 1

EXPLANATION OF PLATE 2

FIGS. 1 *a*, *b*.—*Robulus limbosus* (Reuss). ×60. *a*, side view; *b*, apertural view.
FIG. 2.—*Robulus vicksburgensis* (Cushman). ×60.
FIG. 3.—*Robulus articulatus* (Reuss), var. *texanus* (Cushman and Applin). ×50.
FIG. 4.—*Marginulina fragaria* (Gümbel), var. *texasensis* (Cushman and Applin). ×60.
FIG. 5.—*Dentalina cocoaensis* (Cushman). ×70.
FIG. 6.—*Glandulina laevigata* (d'Orbigny), var. *ovata* Cushman and Applin. ×90. Specimen showing biserial chambers in the early stage.
FIG. 7.—*Nonion inexcavatum* (Cushman and Applin). ×90.
FIGS. 8 *a*, *b*.—Nonion laevis (d'Orbigny), var. *marginatum* Cushman and Ellisor. ×90. *a*, side view; *b*, peripheral view.
FIG. 9.—*Nonionella hantkeni* (Cushman and Applin). ×90.
FIGS. 10 *a*, *b*.—*Nonionella hantkeni* (Cushman and Applin), var. *spissa* Cushman. ×90. *a*, side view; *b*, peripheral view.
FIG. 11.—*Nonionella tatumi* Howe. ×90.
FIGS. 12 *a–c*.—*Nonionella hantkeni* (Cushman and Applin), var. *spissa* Cushman. ×70. *a*, *b*, opposite sides; *c*, peripheral view.
FIGS. 13 *a*, *b*.—*Elphidium eocenicum* Cushman and Ellisor. ×90. *a*, side view; *b*, peripheral view.
FIG. 14.—*Nonion whitsettensis* (Cushman and Applin). ×90.
FIG. 15.—*Operculina oliveri* Cushman. ×15.

Figures drawn by Margaret S. Moore

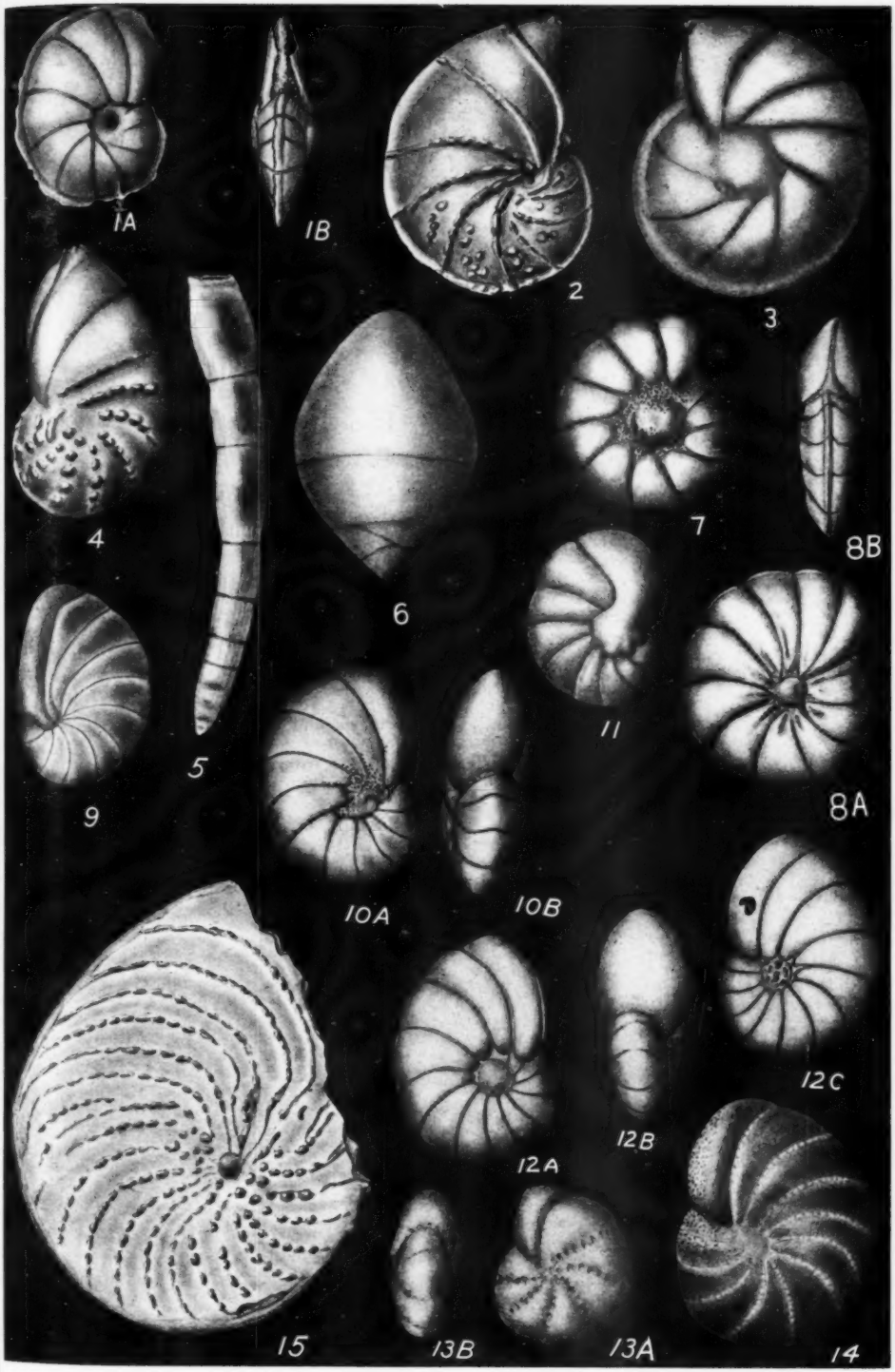

PLATE 2

EXPLANATION OF PLATE 3

FIG. 1.—*Buliminella subfusiformis* Cushman. ×90.
FIG. 2.—*Bulimina pyrula* d'Orbigny. ×50.
FIG. 3.—*Bolivina jacksonensis* Cushman and Applin. ×90.
FIG. 4.—*Bolivina jacksonensis* Cushman and Applin, var. *striatella* Cushman and Applin. ×90.
FIG. 5.—*Bolivina beyrichi* Reuss, var. *carinata* Hantken. ×90.
FIG. 6.—*Bolivina caelata* Cushman. ×70.
FIG. 7.—*Loxostoma hiwaneense* Howe. ×90.
FIG. 8.—*Loxostoma amygdalaeforme* (H. B. Brady), var. *delicatum* Cushman. ×70.
FIG. 9.—*Bifarina vicksburgensis* (Cushman). ×90.
FIGS. 10 *a*, *b*.—*Uvigerina vicksburgensis* Cushman and Ellisor. ×60. *a*, side view; *b*, apertural view.
FIGS. 11, 12.—*Uvigerina alata* Cushman and Applin. ×60.
FIG. 13.—*Uvigerina cocoaensis* Cushman. ×60.
FIG. 14.—*Uvigerina topilensis* Cushman. ×60.
FIG. 15.—*Uvigerina gardnerae* Cushman, var. *texana* Cushman and Applin. ×60.
FIG. 16.—*Angulogerina byramensis* (Cushman). ×90.
FIGS. 17 *a*, *b*.—*Discorbis hemisphaerica* Cushman. ×90. *a*, dorsal view; *b*, ventral view.
FIGS. 18 *a–c*.—*Discorbis hemisphaerica* Cushman. ×90. *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
FIG. 19.—*Eponides pygmaea* (Hantken). ×90.
FIGS. 20 *a–c*.—*Eponides vicksburgensis* Cushman and Applin. ×90. *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
FIG. 21.—*Siphonina jacksonensis* Cushman and Applin. ×90.
FIG. 22.—*Siphonina advena* Cushman. ×90.

Figures drawn by Margaret S. Moore

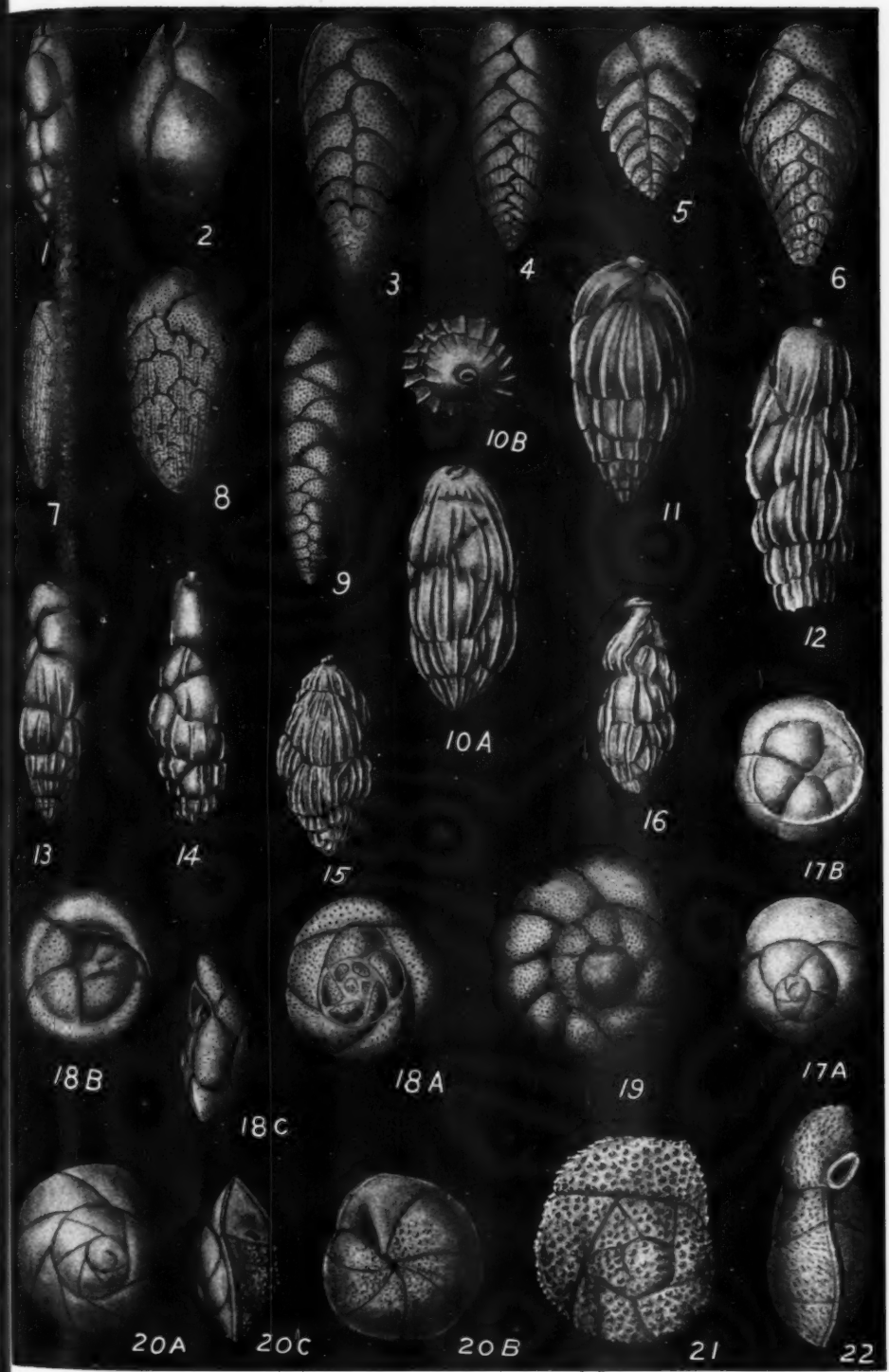
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PLATE 3

EXPLANATION OF PLATE 4

FIGS. 1 *a–c.*—*Valvulineria texana* Cushman and Ellisor. ×90. *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

FIGS. 2 *a–c.*—*Gaudryina vicksburgensis* (Cushman). ×60. *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

FIG. 3.—*Rotalia dentata* Parker and Jones, var. *parva* Cushman. ×90.

FIG. 4.—*Globigerina apertura* Cushman. ×60.

FIGS. 5 *a–c.*—*Anomalina barrowi* Cushman and Ellisor. ×90. *a*, *b*, opposite sides; *c*, peripheral view.

FIGS. 6 *a*, *b.*—*Globorotalia cocoaensis* Cushman. ×90. *a*, dorsal view; *b*, peripheral view.

FIG. 7.—*Anomalina bilateralis* Cushman. ×60. Jackson variety.

FIG. 8.—*Anomalina jacksonensis* (Cushman and Applin), var. *texana* (Cushman and Applin). ×90.

FIG. 9.—*Anomalina bilateralis* Cushman. ×90. Specimen showing exceptionally heavy limbate sutures and unusual central ornamentation. Vicksburg variety.

FIGS. 10 *a*, *b.*—*Amonalina jacksonensis* (Cushman and Applin). ×90. *a*, *b*, opposite sides.

Figures drawn by Margaret S. Moore

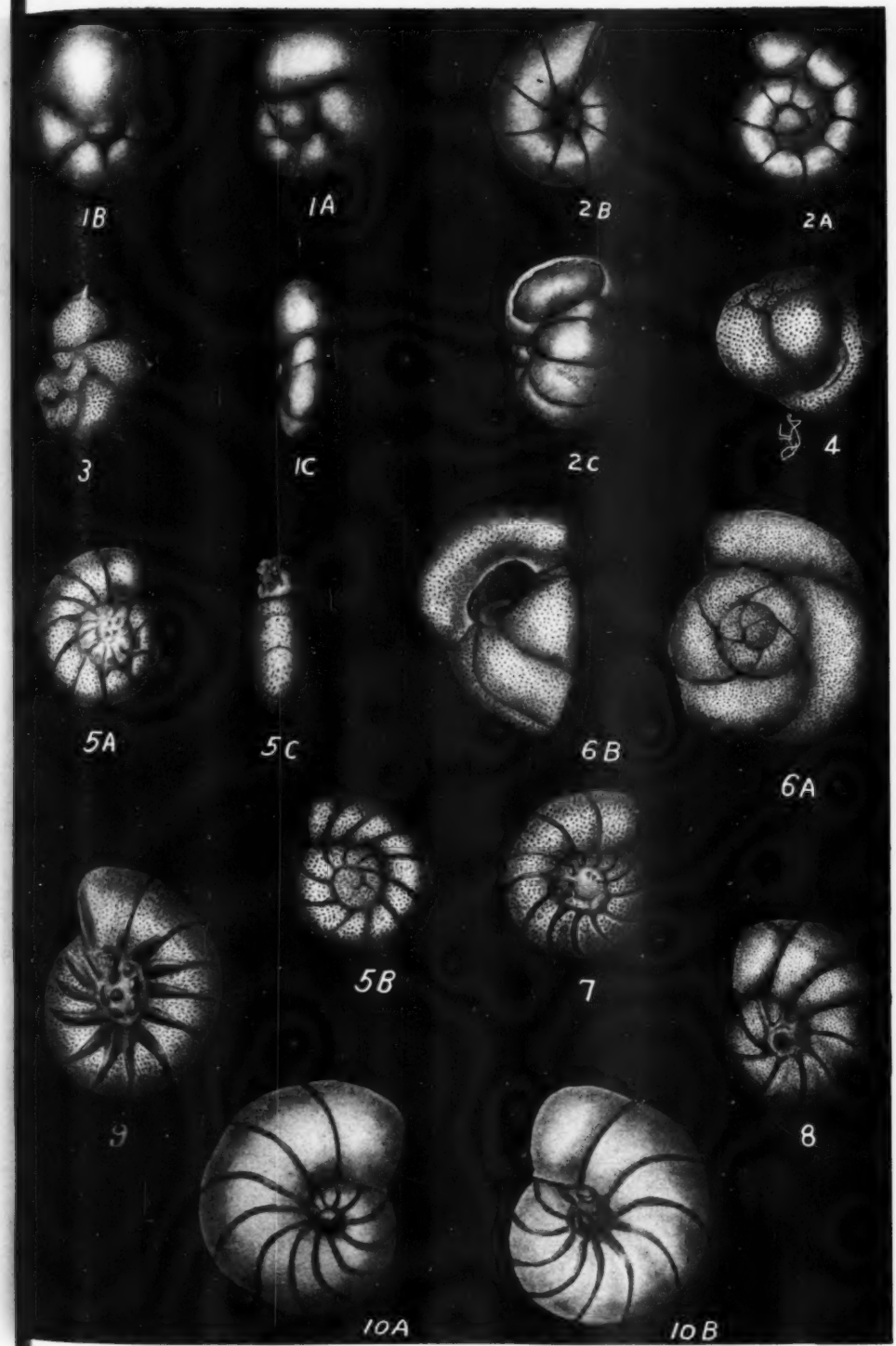

PLATE 4

EXPLANATION OF PLATE 5

FIGS. 1 *a–c.*—*Anomalina jacksonensis* (Cushman and Applin), var. *limbosa* Cushman and Ellisor. ×90. *a*, *b*, opposite sides; *c*, peripheral view.

FIGS. 2 *a–c.*—*Cibicides yazooensis* Cushman. ×90. *a*, *b*, opposite sides; *c*, peripheral view.

FIGS. 3, 4*a*, 4*b*.—*Cibicides pseudoungerianus* (Cushman). ×60. Fig. 3, dorsal view of flat variety; Fig. 4*a*, dorsal view of convex species; Fig. 4*b*, peripheral view of same species.

FIGS. 5 *a*, *b*.—*Cibicides yazooensis* Cushman. ×60. *a*, *b*, opposite sides. Specimen with unusual heavy limbate sutures.

FIGS. 6, 7.—*Cibicides mississippiensis* (Cushman). ×90. Fig. 6*a*, side view; *b*, peripheral view; Fig. 7 *a*, *b*, opposite sides; *c*, peripheral view.

Figures drawn by Margaret S. Moore

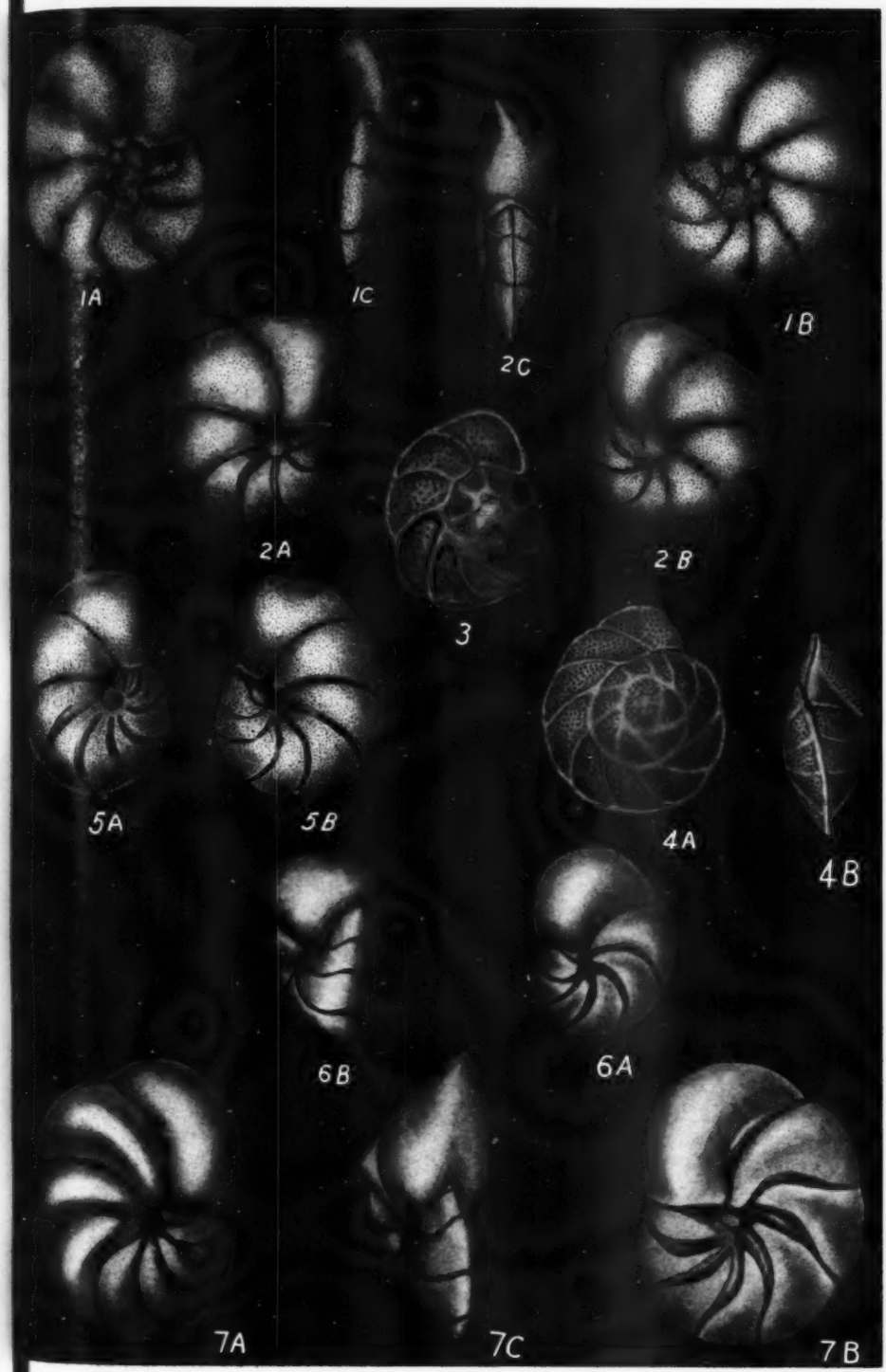

PLATE 5

EXPLANATION OF PLATE 6

FIGS. 1 *a–c.*—*Siphonina carltoni* Cushman and Ellisor, n.sp. ×60. 1 *a*, dorsal view; 1 *b*, ventral view; 1 *c*, peripheral view.
FIG. 2.—*Textularia adalta* Cushman, var. ×70.
FIG. 3.—*Dyocibicides danvillensis* Howe and Wallace. ×60.
FIGS. 4 *a*, *b*.—*Tubulogerina eocenica* Cushman and Ellisor, n.sp. ×145. *a*, front view; *b*, apertural view.
FIG. 5.—*Hantkenina alabamensis* Cushman. ×70.
FIG. 6.—*Marginulina cocoaensis* Cushman. ×50.
FIG. 7.—*Quinqueloculina hauerina* d'Orbigny. ×50.
FIGS. 8 *a–c.*—*Massilina humblei* Cushman and Ellisor, n.sp. ×50. *a*, *b*, opposite views; *c*, apertural view.
FIG. 9.—*Planularia ouachitaensis* Howe and Wallace. ×40.

Figures drawn by Margaret S. Moore

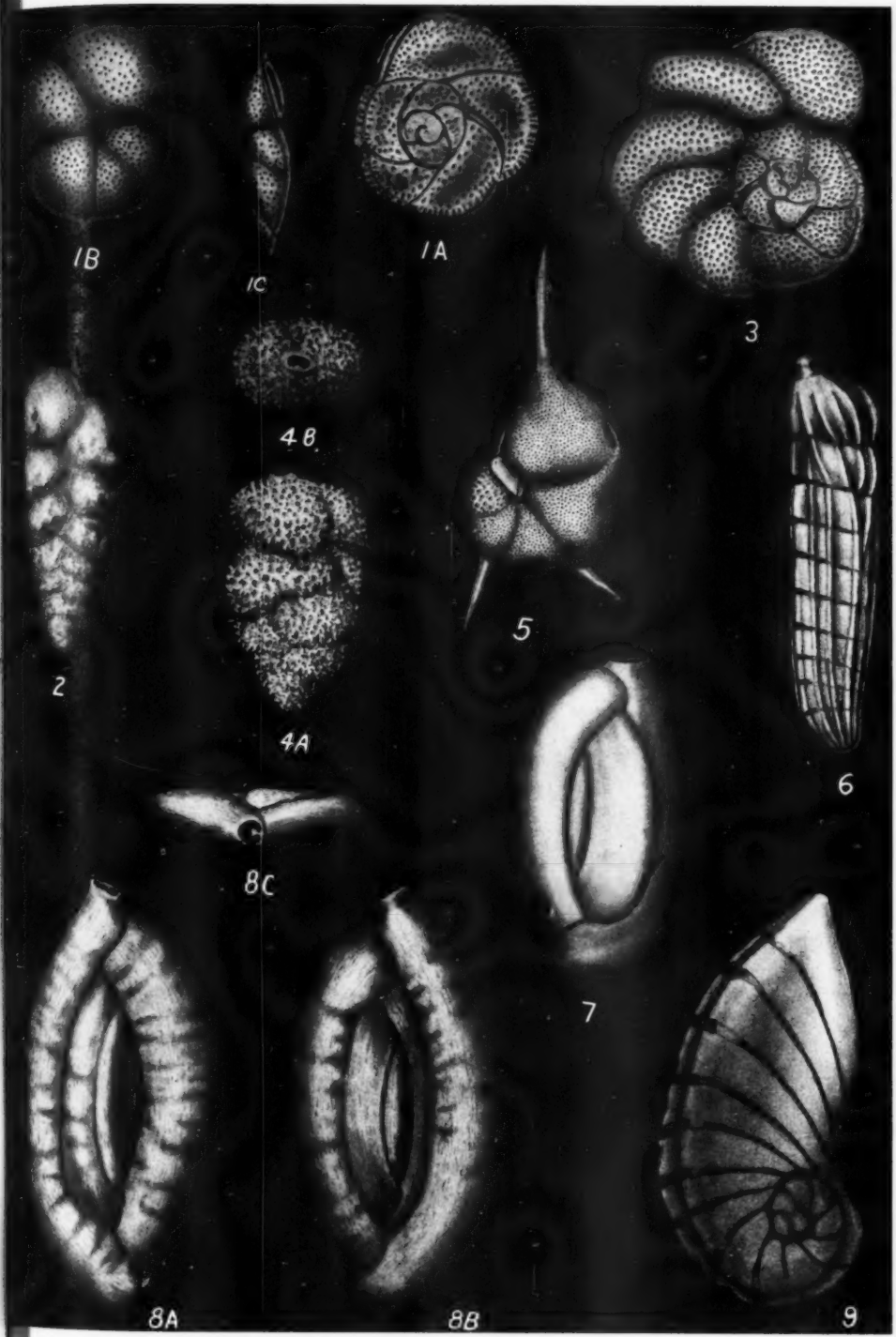

PLATE 6

EXPLANATION OF PLATE 7

FIG. 1.—*Sigmomorphina jacksonensis* (Cushman), var. *costifera* (Cushman). ×70.
FIG. 2.—*Pseudopolymorphina dumblei* (Cushman and Applin). ×60.
FIG. 3.—*Guttulina spicaeformis* (Roemer). ×70.
FIG. 4.—*Marginulina pediformis* Bornemann. ×70.
FIG. 5.—*Bulimina jacksonensis* Cushman. ×60.
FIGS. 6 *a–c*.—*Discorbis farishi* Cushman and Ellisor, n.sp. ×90. *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
FIGS. 7 *a*, *b*.—*Nonion scaphum* (Fichtel and Moll), var. *inflatum* Cushman and Ellisor, n.sp. ×70. *a*, side view; *b*, apertural view.
FIG. 8.—*Nonion chapapotensis* Cole. ×70.
FIGS. 9 *a*, *b*.—*Nonionella hantkeni* (Cushman and Applin), var. *fayettei* Cushman and Ellisor, n.var. ×70. *a*, side view; *b*, apertural view.
FIGS. 10 *a*, *b*.—*Nonion inexcavatus* (Cushman and Applin), var. ×70. *a*, side view; *b*, apertural view.
FIG. 11.—*Ammobaculites hockleyensis* Cushman and Applin. ×50.
FIGS. 12 *a*, *b*.—*Robulus propinquus* (Hantken). ×70. *a*, side view; *b*, apertural view.
FIG. 13.—*Pyrgo inornata* (d'Orbigny), var. *danvillensis* Howe and Wallace. ×90.
FIG. 14.—*Triloculina rotunda* d'Orbigny, var. ×60.

Figures drawn by Margaret S. Moore

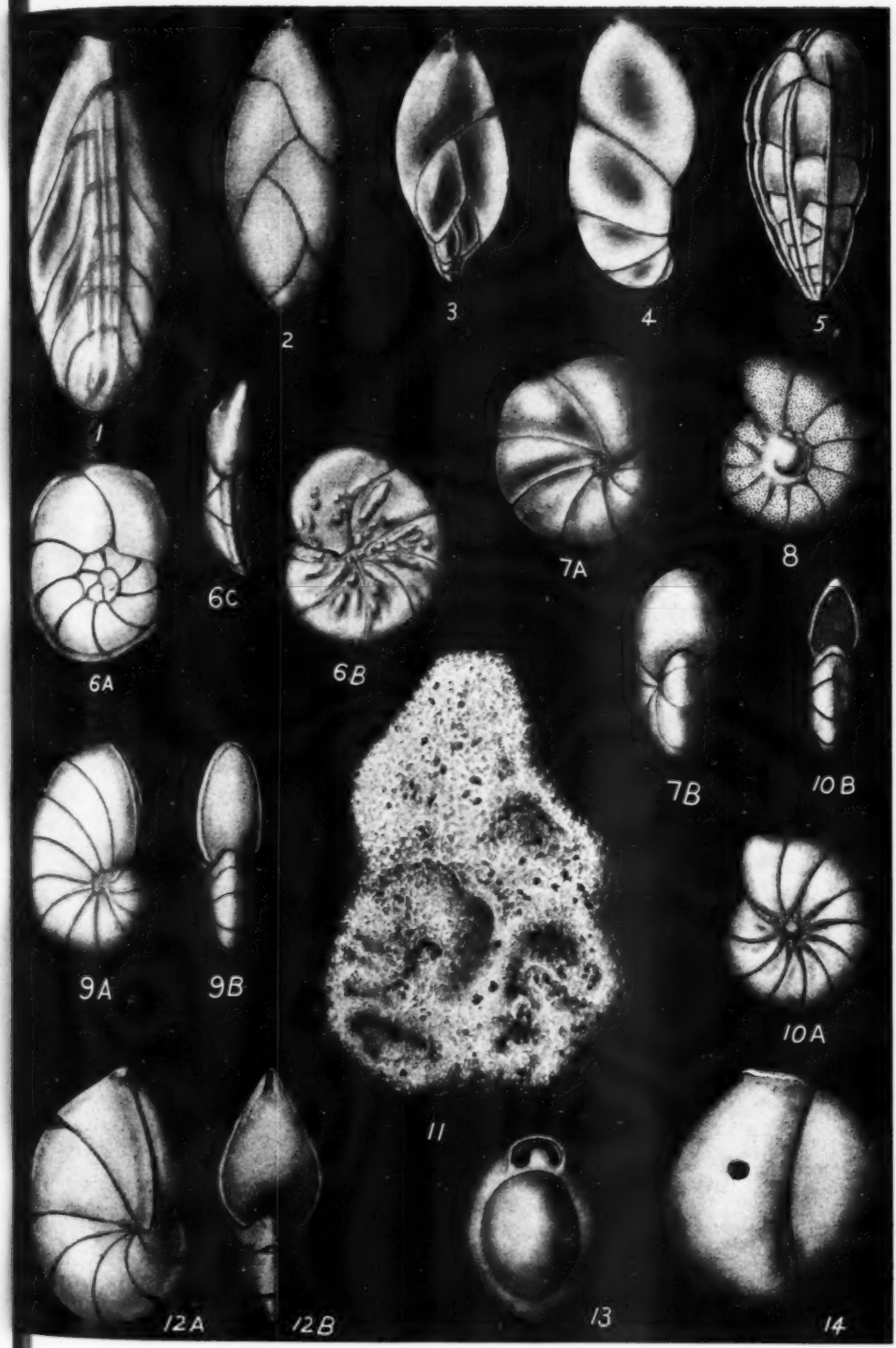

PLATE 7

Another change in conditions was brought about when the sea invaded the area, depositing the Dilworth sand, which has been traced across the area. It is overlapped by the Catahoula in eastern Fayette County and possibly a short distance east. The Dilworth sand marks the beginning of marine conditions during which the Whitsett formation was deposited.

The section shows the variation of the Whitsett formation. The well-defined mappable units of Atascosa County do not occur in East Texas. The Olmos sand disappears in eastern Atascosa County; the Fashing clays and Calliham sand disappear in western Karnes County, both on the surface and in the wells. This accounts for the difference in the thickness of the Whitsett (Fayette) in the wells south of Atascosa and Karnes counties.

In the eastern part of Texas there is a difference of opinion as to the top of the Whitsett. Burford and Olcott place the top at the base of the Chita sand. The writer places the top at the first fossil horizon, placing the interval between that and the Chita in the Frio or Vicksburg. As the Vicksburg is present down the dip in the wells, there is the probability that the Vicksburg may occur on the surface, though there is no paleontological evidence to substantiate this. In the Crater Oil Company's Anthony Shoals No. 1, in Sabine County, Vicksburg fossils were found in cuttings from 367 to 397 feet. The well commences in the Catahoula "rice sands."

Section EE.—In Louisiana and in Sabine County, Texas, the three members of the Jackson group are highly fossiliferous clays. Lithologically they are the same, each formation consisting of a marly phase, which is highly fossiliferous, and a chocolate-colored, bentonitic clay phase with a scant fauna. *Textularia hockleyensis* Cushman and Applin occurs in these chocolate clays in both the Whitsett and the McElroy. It is on the faunal assemblage of the marly phase that the divisions of the three units are made rather than on the lithologic character. In the wells across Texas from Sabine River to Duval County the section is the same as the surface section in Louisiana and eastern Sabine County.

Section *EE*, which includes wells from Live Oak County to Sabine River, is given to show the occurrence of the three formations, Whitsett, McElroy, and Caddell, in the wells. The Caddell varies in thickness from 130 to 220 feet. It is highly fossiliferous.

The McElroy varies from 500 to 800 feet. The basal half is the highly fossiliferous phase which corresponds with the Wooley's Bluff clays. The upper part is ordinarily poorly fossiliferous and corresponds with the Manning beds. Down the dip, in the wells, the entire McElroy

is found. Toward the outcrop the McElroy thins, due to the thinning of the lower part, or Wooley's Bluff zone, which is overlapped by the upper part, or Manning beds.

The contact of the Whitsett and the McElroy is marked by an excellent zone fossil, *Massilina pratti* Cushman and Ellisor, a fossil that is very limited in range stratigraphically and has been traced on the surface from Danville Landing on Ouachita River, Louisiana, to Sabine River, then across Texas in the wells to the Lucas field in Live Oak County. The *Massilina pratti* zone has not been found west of the Lucas field in Live Oak County. This zone is ordinarily 100 feet thick, but in some areas it is 150 feet thick.

Massilina pratti is a better marker than *Textularia hockleyensis* because it is limited in its vertical range, and because it marks the beginning of a new formation. *Textularia hockleyensis* ranges up into the Whitsett in various areas, both in the wells and on the surface.

The variation in thickness of the Whitsett as shown in the wells is the result of the unconformity at the top of the Whitsett, which is greater in some areas than in others. There is the general unconformity with a thinning eastward and with local unconformities due to structure.

In Duval County and westward the section changes. The fauna above the Caddell becomes scant and as the few species present range from the top of the Whitsett to the Caddell, it is not possible to place definitely the contact between the Whitsett and the McElroy.

SUMMARY

In this paper it is shown that the Jackson in Texas is divided into three major divisions or formations: Caddell, McElroy, and Whitsett. Due to the complicated nature of the Jackson sediments, it has been found desirable to divide the formations into smaller units, zones, or members.

The Caddell on the surface is divided into two phases on the basis of lithologic character and micro-paleontology. In the wells the divisions can be made on the basis of micro-fossils as well.

The McElroy on the surface is divided into a very fossiliferous lower member (Wooley's Bluff clays) and a partly nonmarine upper member (Manning beds) separated by a fossiliferous sand series (Wellborn sands). West of Angelina County the Wellborn sands overlap the Wooley's Bluff clays.

The Whitsett formation, the former restricted Fayette of the writer, is a very complicated formation. The top of the Whitsett is at Olmos Creek, south of Whitsett, Live Oak County. From this point

north toward Campbellton a complete section is found. Eastward from the eastern edge of Atascosa County the Catahoula overlaps older and older Whitsett beds, so that in Fayette County no Whitsett is present in the section due south of Muldoon. There is an unconformity at the top of the Whitsett as shown in the wells close to the outcrop as well as the overlap of the Catahoula on the surface.

In the wells there is a regional unconformity at the top of the Whitsett from west to east, also local unconformities due to structures. These conclusions concerning the unconformities in the wells are based on the faunal zones into which the Whitsett in the wells can be divided. On the surface the members are mappable units which the field geologist can follow in the field. For the micro-paleontologist's purposes the Whitsett can conveniently be divided into faunal zones, one of which is the *Massilina pratti* zone.

In this paper an attempt is made to correlate the surface and subsurface sections. The Louisiana surface section is the same as the Texas subsurface sections. In Texas, conditions of deposition were different, so that a complicated section was developed with many changes in lithologic character with many mappable units, overlaps, and unconformities.

A section from the outcrop to the coast shows the presence of the Vicksburg in the wells. In the western part it is overlapped some distance down the dip from the outcrop by the Frio. In the eastern part of the area definite Vicksburg approaches very near the outcrop and probably does crop out, but as yet there is no paleontological proof of this.

From its stratigraphic position in the wells the age of the Frio clays is Lower Oligocene, but younger than those beds which contain plentiful Vicksburg fauna. The Frio of this paper includes both the Frio and the Fant of Bailey. In the western area the Frio has its greatest development.

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THE ZONE OF EXOGYRA CANCELLATA TRACED TWENTY-FIVE HUNDRED MILES[1]

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Washington, D. C.

ABSTRACT

The zone of *Exogyra cancellata* forms the lower part of the *Exogyra costata* zone in the Upper Cretaceous and ranges in thickness from 4 feet in New Jersey to 200 feet or more in central Texas; in terms of the European section it is upper Campanian or lower Maestrichtian in age. This zone has been traced, with interruptions, through various formations, from the Navesink Highlands of New Jersey to Cardenas in the state of San Luis Potosi, Mexico. In Texas the zone forms the lower part of the Navarro formation, overlying the Taylor marl, and overlain by the Nacatoch sand member of the Navarro. From New Jersey to central Texas the zone is characterized by *Exogyra cancellata* and *Anomia tellinoides*, both of which are restricted in their stratigraphic range to the zone. A dozen or more of the other molluscan species that occur in the zone, but are not restricted to it, have the same extended geographic range. This assemblage indicates a fairly uniform set of environmental conditions from the northern end of the Atlantic Coastal Plain to the Gulf region. The occurrence of rudistids in the *Exogyra cancellata* zone in Texas indicates a tropical climate there, and points to a climate not colder than subtropical in eastern North America as far north as New Jersey. The presence of the zone at the surface in structural uplifts on the flanks of the Palestine, Keechi, Rayburn, and Prothro salt domes, indicates an extended down-dip spread of the zone, which at the Rayburn dome reaches a known maximum of 115 miles.

A fossil zone may be defined as any bed, or closely associated group of beds, containing one or more characteristic fossils, and traceable by means of these fossils away from the place of the original differentiation of the zone. The tracing of fossil zones is important, or even essential, in the determination of the age and stratigraphic relations of a series of sedimentary deposits. The thinner a fossil zone, and the farther it can be traced, the more useful it becomes to the stratigrapher. A fossil zone that can be traced for a distance of 2,500 miles or more is a zone of reference of utmost importance in determining the age relationships of beds below and above it throughout the length of its occurrence.

In the steep north-facing slope of the Navesink Highlands, about 0.6 mile east of Bay View Avenue station at Atlantic Highlands, Monmouth County, New Jersey, a fossiliferous bed about 4 feet thick crops out only 30 feet above tide level of Raritan Bay. The bed con-

[1] Read before the Paleontology and Mineralogy Division of the Association at the Houston meeting, March 24, 1933. Manuscript received, August 3, 1933. Published by permission of the director, United States Geological Survey.

[2] United States Geological Survey.

tains many poorly preserved fossil mollusks, mostly internal molds, among which was found one imperfect shell of *Exogyra cancellata*. This is the northernmost exposure of a fossil zone that has been named the zone of *Exogyra cancellata*, because that easily recognizable member of the oyster family especially characterizes the zone (Fig. 1).

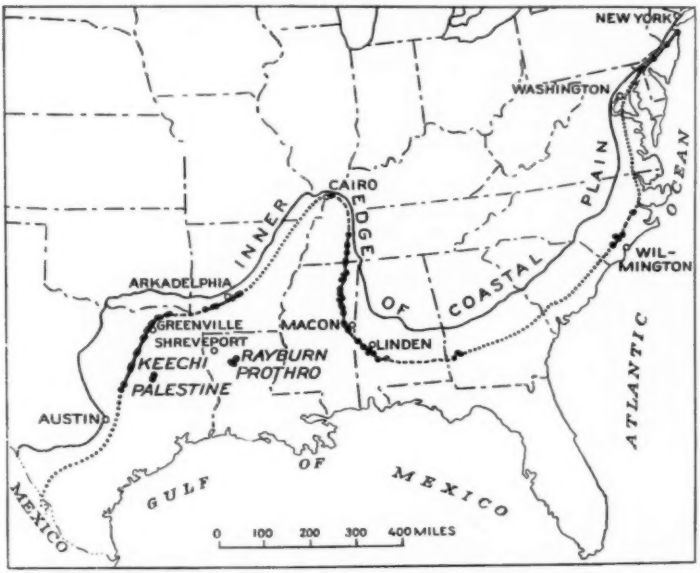

FIG. 1.—Map showing line along which *Exogyra cancellata* has been collected in Atlantic and Gulf Coastal Plain, including also occurrences on salt-dome structures. Large circular dots indicate single localities; large oval dots indicate two or more localities; dashed lines indicate parts of zone of outcrop along which no specimens have been collected; small dots indicate stretches along which zone is overlapped by younger formations.

At the Navesink Highlands, and indeed throughout New Jersey, the *Exogyra cancellata* zone is coincident with a formation known as the Mount Laurel sand, the basal formation of the Monmouth group. This sand is also the basal part of a thicker zone known as the *Exogyra costata* zone, which in New Jersey coincides with the Monmouth group. The Mount Laurel sand is underlain by the Wenonah sand, the uppermost formation of the Matawan group, and incidentally the uppermost part of another zone, known as the *Exogyra ponderosa* zone. The Mount Laurel sand is unconformably overlain by the Navesink marl, the next higher formation of the Monmouth group.[3]

[3] The following are references to a few papers, by the present writer and others,

The next definitely identified exposure of the *Exogyra cancellata* zone south of Navesink Highlands is in a bluff on Crosswicks Creek, 0.6 mile north of New Egypt, Ocean County, New Jersey; this locality was brought to the writer's attention by Erling Dorf of Princeton University. Here 6 feet of the Mount Laurel sand is exposed above water level, and is unconformably overlain by the Navesink marl. In a bed 3–4 feet above water level the sand is replete with well preserved shells of *Exogyra cancellata*, associated with many shells of *Gryphaea mutabilis* Morton, and with vast numbers of the guards of the cuttlefish-like cephalopod, *Belemnitella americana* (Morton). Here and there among the other fossils are shells of *Anomia tellinoides*

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in which are summary descriptions of the formations and fossil zones mentioned in this paper, and in which are correlation charts and illustrations of the two index fossils, *Exogyra cancellata* Stephenson and *Anomia tellinoides* Morton. The list is incomplete with respect to the historical development of knowledge concerning the formations, zones, and fossils.

W. B. Clark, E. W. Berry, Julia A. Gardner, and others, "Upper Cretaceous" (2 vols., 1916), *Maryland Geol. Survey*, pp. 70–74, 566–68, 610–11; Pl. 27, Fig. 3; Pl. 35, Figs. 3, 4.

Carle H. Dane, "Upper Cretaceous Formations of Southwestern Arkansas," *Arkansas Geol. Survey Bull. 1* (1929), pp. 90–114; Pl. 1; Pl. 18, Fig. 2; Pl. 20. Fig. 1.

Carle H. Dane and L. W. Stephenson, "Notes on the Taylor and Navarro Formations in East-Central Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 1 (January, 1928), pp. 55–58; Pl. 2.

Sidney Powers, "Interior Salt Domes of Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 1 (January, 1926), pp. 35–53.

W. C. Spooner, "Interior Salt Domes of Louisiana," *Geology of Salt Dome Oil Fields* (Amer. Assoc. Petrol. Geol., 1926), pp. 297–304, 312–17.

Lloyd William Stephenson, "Cretaceous" [of Georgia], in "The Coastal Plain of Georgia," *Geol. Survey Georgia Bull. 26* (1911), pp. 187–90; map, p. 58.

Idem, "Cretaceous Deposits of the Eastern Gulf Region and Species of Exogyra from the Eastern Gulf Region and the Carolinas," *U. S. Geol. Survey Prof. Paper 81* (1914), pp. 21–24, 34–40, 53–55; Pl. 9; Pl. 10; Pl. 21, Figs. 1, 2; Pl. 22, Figs. 2–4.

Idem, "A Contribution to the Geology of Northeastern Texas and Southern Oklahoma," *U. S. Geol. Survey Prof. Paper 120* (1918), pp. 157–58; Pl. 17.

Idem, "Invertebrate Fossils of the Upper Cretaceous Formations" [of North Carolina], in "The Cretaceous Formations of North Carolina," *North Carolina Geol. and Econ. Survey*, Vol. 5, pt. 1 (1923), pp. 11–13, 22–35, 182–85, 223–25; Pl. 50, Figs. 5, 6; Pl. 51, Figs. 1, 2; Pl. 60, Figs. 1–7.

Idem, "The Mesozoic Rocks" [of Alabama], in "Geology of Alabama," *Geol. Survey of Alabama Spec. Rept. 14* (1926), pp. 237–45; Pl. 87, Figs. 1–3.

Idem, "Notes on the Stratigraphy of the Upper Cretaceous Formations of Texas and Arkansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11, No. 1 (January, 1927), pp. 13–17; Pl. 1.

Idem, William N. Logan and Gerald A. Waring, "The Ground-Water Resources of Mississippi," *U. S. Geol. Survey Water-Supply Paper 576* (1928), pp. 36–43; Pl. 2.

Lloyd William Stephenson, "Correlation of the Upper Cretaceous or Gulf Series of the Gulf Coastal Plain," *Amer. Jour. Sci.*, Vol. 16 (December, 1928), pp. 492–93; Fig. 1, correlation chart.

Idem, "Unconformities in Upper Cretaceous Series of Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 10 (October, 1929), pp. 1331–32; Pl. 13.

Bruce Wade, "The Fauna of the Ripley Formation on Coon Creek, Tennessee," *U. S. Geol. Survey Prof. Paper 137* (1926), pp. 6–7, 58, 69–70; Pl. 16, Figs. 1–3; Pl. 23, Figs. 3, 4.

Stuart Weller, "Cretaceous of New Jersey," in "Paleontology," *Geol. Survey of New Jersey*, Vol. 4 (1907), pp. 103–36, 496–99; Pl. 54, Fig. 15.

Morton, a highly important index fossil, restricted to this zone, and a companion fossil to *Exogyra cancellata* at many of its occurrences within the borders of the United States.

The next locality of *Exogyra cancellata* is in a road-cut section at Mullica Hill, Gloucester County, New Jersey, where the shells of this species are found associated with *Belemnitella americana*, in the Mount Laurel sand, 6 feet below the base of the Navesink marl.

In Delaware and Maryland the zone forms the lower part of the undivided Monmouth formation, and *Exogyra cancellata* and *Anomia tellinoides* are both present in the zone; the zone is unconformably underlain by the Matawan formation. The former species has been recorded by Julia Gardner from 6 localities on and near the Chesapeake and Delaware Canal in Delaware, between Summit Bridge, 3 miles east of the state line, and Delaware City. Although 5 of these localities are correlated by Gardner with the Matawan formation, subsequent investigations by the present writer indicate that they should have been referred to the Monmouth formation. The matrix in which the shells occur here is very much like the Mount Laurel sand. The species is also listed from the head of Bohemia Creek in New Castle County, Delaware, and from Bohemia Mills in Cecil County, Maryland.

Anomia tellinoides is recorded from one locality on the canal in Delaware.

Farther south in Maryland the zone is overlapped by younger formations and does not appear at the surface between Maryland and Pitt County, North Carolina.

In North Carolina the zone makes up the lower part of the Peedee formation. *Exogyra cancellata* has been collected from the following localities in the zone in this state: pits on land of J. F. Brooks, 2 miles east of Grifton, Pitt County; on Black River near Sparkleberry Landing, Bladen County; on Cape Fear River at Black Rock, Daniels, Indian Wells, Kellys Cove, Robinsons, and Donohue Creek landings, Bladen County; on the north shore of Waccamaw Lake, Columbus County. *Anomia tellinoides* occurs on Cape Fear River at Daniels and Robinsons landings. Somewhere south of Waccamaw Lake the zone is again overlapped by younger beds, and lies deeply buried in South Carolina and in eastern Georgia.

The next appearance of the zone is in Marion County, Georgia, where it forms a part of the group of beds known as the Ripley formation. *Exogyra cancellata* has been recorded from the following localities in Georgia: Biven's plantation on Dry Creek, 3 miles west of Pineville, Marion County; cuts of Seaboard Air Line Railway within

1.25 miles north of Renfroes Station, Stewart County; Johnsons Hill, 4 miles north of Lumpkin, Stewart County. *Anomia tellinoides* occurs at the last named locality.

The Ripley of Georgia, including the *Exogyra cancellata* zone, extends westward into Alabama, but no collections have been made from the zone between Chattahoochee and Alabama rivers. The following is a list of the localities at which *Exogyra cancellata* has been collected or noted in Alabama: sand of the Ripley formation on Alabama River, 0.5 mile above Portland, Dallas County; sand of the Ripley formation at Rocky Bluff, Alabama River, 1 mile above Prairie Bluff, Wilcox County; sand of the Ripley formation on Dayton road, 3.8 miles north of Thomaston, Marengo County; sand of the Ripley formation on Linden road, 2.1 miles south of Old Spring Hill, Marengo County; Selma chalk on Demopolis road, 0.8 mile, and 1.9 miles northwest of Old Spring Hill, Marengo County; Selma chalk at Bartons Bluff, Tombigbee River, 9 miles below Demopolis, Marengo County; sandy facies of Selma chalk, on Epes road, about 6 miles north of Livingston, Sumter County.

Anomia tellinoides has been collected along the strike of the *Exogyra cancellata* zone in Alabama, as follows: Selma chalk on the Gallion road 9 or 10 miles north of Linden, Marengo County; Selma chalk at Bartons Bluff, Tombigbee River, 9 miles below Demopolis; Selma chalk near Simmons Landing, Tombigbee River, 7 miles below Demopolis; sandy facies of Selma chalk, Epes road about 6 miles north of Livingston.

From east-central Mississippi the zone is traceable in a narrow strip stratigraphically somewhat above the middle of the Selma chalk, northward to and beyond the Tennessee state line; in northern Mississippi the zone lies in the upper part of the Selma chalk, below the more sandy and argillaceous beds of the Ripley formation. *Exogyra cancellata* has been collected from 18 localities along this strip in Mississippi, and *Anomia tellinoides* was associated with it at 9 of the localities. The localities in Mississippi are as follows: cut of Mobile and Ohio Railroad, 3 miles south of Macon, Noxubee County; bluff on Oaknoxubee River, 0.25 mile below Macon (with *A. tellinoides*); Brane plantation, 2.5 miles south of Macon (with *A. tellinoides*); public road, 3 miles northwest of Macon (with *A. tellinoides*); West Point road, near west end of Line Creek bridge, 1 mile east of Cedar Bluff, Clay County (with *A. tellinoides*); Houston-West Point road, about 2 miles southeast of Caradine store, Clay County (with *A. tellinoides*); same road, 0.25 mile southeast of Caradine store (with *A. tellinoides*); gullies south of Troy-Shannon road, 3 miles east of Troy,

in Lee County; washes south of Pontotoc-Tupelo road, 6 miles west of Tupelo, Lee County; Houston road, 4.5 miles west of Okolona, Chickasaw County; same road, 3 miles west of Okolona; same road, 2 miles west of Okolona; bald spots and gullies near Pontotoc road, 2.5 miles northwest of Okolona; gullies north of New Albany road, east side of Tishomingo Creek valley, 0.25 mile west of Bethany, Lee County (with *A. tellinoides*); Booneville-Ripley road, 1 mile west of Blackland, Prentiss County; gullies near road 3.5 miles northwest of Booneville, Prentiss County; Bald Knob, Joseph Reynold's place, 3 miles west of Corinth, Alcorn County (with *A. tellinoides*); cut of Southern Railway, 2.75 miles west of Corinth (with *A. tellinoides*).

Across the state line in Tennessee, where the base of the Ripley has descended to a slightly lower position in the section, the *Exogyra cancellata* zone embraces the upper part of the Selma chalk, and the overlying Coon Creek tongue of the Ripley formation. In this area in southern Tennessee the Selma is merely a tongue of impure chalk extending northward from the main body of that formation in Mississippi, and the Coon Creek is a tongue of marine sand and clay extending northward from the base of the Ripley formation. The occurrence of *Exogyra cancellata* has been recorded from 3 localities in the Selma and 2 localities in the Coon Creek including the classic locality on Coon Creek, McNairy County, from which Bruce Wade collected and described an abundant and excellently preserved fauna of mollusks and other marine organisms.

The localities in the Selma chalk are as follows: Blue Cut, Mobile and Ohio Railroad, just north of the Mississippi state line, McNairy County; Selmer road, 3 miles west of Adamsville, McNairy County; Highway No. 17, 2.2 miles east of Enville, Chester County.

The occurrences in the Coon Creek tongue are: Dave Week's place on Coon Creek, 7.5 miles north of Adamsville, McNairy County; old Adamsville road, 8.6 miles (by the road) east of Lexington, Henderson County. *Anomia tellinoides* is recorded from the Coon Creek tongue at the last named locality. The specimen from Dave Week's place on Coon Creek, which Wade referred to this species, belongs instead to *Anomia argentaria* Morton.

That the zone of *Exogyra cancellata* extended to the head of the Mississippi embayment is shown by the finding of a typical shell of that species in an excavation for an Ohio River bridge pier near Cairo, Illinois. This shell is preserved in the State Natural History Museum at Springfield, Illinois (specimen No. 8358).[4]

[4] L. W. Stephenson, *U. S. Geol. Survey Prof. Paper 81* (1914), p. 55.

From the head of the Mississippi embayment to Clark County, Arkansas, the *Exogyra cancellata* zone is overlapped and concealed by Tertiary and Pleistocene deposits. In southwestern Arkansas the zone is included within the Saratoga chalk, but the upper part of the underlying Marlbrook contains a large, partly cancellated variety of *Exogyra* that is probably ancestral to the later, more typical form of the cancellated species, and also a few fairly typical shells of that species. Unconformities separate the Saratoga from the Marlbrook marl below and the Nacatoch sand above. *Anomia tellinoides* has not been recorded from Arkansas, but it probably will be found in the Saratoga chalk. *Exogyra cancellata* is recorded from 7 localities in the Saratoga chalk, as follows: small branch flowing northeast from free tourist camp at north edge of Arkadelphia, Clark County; Big Deciper Creek, near the crossing of the upper road to Gurdon, 5.4 miles west-southwest of Arkadelphia; Okolona road, in SE. ¼, Sec. 30, T. 7 S., R. 20 W., 7.8 miles west-southwest of Arkadelphia; gullied north-facing slope in SE. ¼, NE., ¼, Sec. 29, T. 8 S., R. 21 W., 5 miles east by north of Okolona, Clark County; old Marlbrook plantation, 6 or 7 miles northeast of Washington, Hempstead County; Ozan road, 3.3 miles north of Washington; and 0.75 mile north by west of Columbus, Hempstead County.

The trail of the *Exogyra cancellata* zone from northeastern Texas to Milam County, Texas, is marked by a line of 33 known localities where the shells of this species occur, and along the same line *Anomia tellinoides* has been collected from 10 localities. At 6 of the localities the two species occur in close association. In Texas the zone consists of a maximum of more than 200 feet of more or less sandy and glauconitic marl, and forms the lowermost of four members composing the Navarro formation. In central Texas where exposures have permitted an examination of the contact the zone is seen to be separated from the Taylor marl below by an unconformity marked by a thin zone of phosphatic nodules and phosphatic molds of mollusks. The exact contact of the zone with the overlying Nacatoch sand has not been observed. In Texas the ammonite genus *Placenticeras* ranges upward into the zone but has not been found above it; in the zone the genus is represented by one large undescribed species. The ammonite genus *Sphenodiscus* has been identified from the three uppermost members of the Navarro, but has not been found in the *Exogyra cancellata* zone. In this connection it is interesting to note that F. L. Whitney,[5] of the University of Texas, has found a small ammonite

[5] Oral communication.

in the upper part of the Taylor marl in Travis County, which both he and J. B. Reeside, to whom the specimen was submitted, agree belongs to an undescribed species of *Sphenodiscus*. This indicates that *Sphenodiscus* has a lower stratigraphic range in Texas than has heretofore been known.

In Texas, and indeed throughout the Atlantic and Gulf Coastal Plain, the large smooth forms of *Exogyra*, commonly referred to *E. ponderosa* Roemer, are found in beds stratigraphically lower than the *Exogyra cancellata* zone, and no authentic occurrence of that species is known from the *cancellata* zone proper. A molluscan fauna that includes many undescribed species has recently been found in concretions in this zone in Navarro County, Texas.

In the southern part of Milam County, Texas, both the *Exogyra cancellata* zone and the overlying Nacatoch sand member are overlapped by younger Cretaceous strata and neither of these members is seen again in surface outcrops between Milam County and the Rio Grande; however, the large, partly cancellated ancestral form of *Exogyra*, like the one at the top of the Marlbrook in Arkansas, is present in the top of the Taylor in Williamson and Travis counties.

The known distribution of *Exogyra cancellata* in the main belt of outcrop of the zone in Texas is as follows: gully west of Paris highway, 7.25 miles northeast of Cooper, Delta County; gully west of same highway, 7.1 miles northeast of Cooper; cut of Texas Midland Railroad, 0.5 mile north of Cooper; branch east of Texas Midland Railroad, 0.25 mile north of Cooper; near Cooper; creek south of Texas Midland Railroad, 2 miles west of Cooper; Texas Midland Railroad, 4.5 miles west of Cooper; cut of Texas Midland Railroad, 0.25 mile southwest of Neylandville flag station, Hunt County; Bankhead highway, 5.3 miles northeast of Greenville, Hunt County; same highway, 4.3 miles northeast of Greenville; near same highway half a mile east of Liberty School, 3.5 miles northeast of Greenville; field south of the fair grounds at the southeastern edge of Greenville; road ditch at the northeastern corner of the fair grounds, Greenville; Dixon road, 2–2.12 miles southeast of the post office at Greenville; Dallas road, 2.8 miles northeast of Royce City, in Collin (?) County; Dallas road, 2.5 miles northeast of Royce City, Collin County; Terrell road, 1.5 miles southeast of Chisholm, Rockwall County; gully in field northeast of Rockwall road, 5 miles northwest of Terrell, Kaufman County; Forney road, 4.6 miles west of Terrell; Crandall road 3.9 miles west of Kaufman, Kaufman County; Dallas highway, 4 miles west of Kaufman; gully a few hundred feet east of the Crandall road, 4.25 miles west of Kaufman; cut of Texas and New Orleans

Railroad, 1.5 miles east of Gastonia, Kaufman County; cut of same railroad, a mile east of Gastonia; Drane road, 5 miles west-southwest of Corsicana, Navarro County; Corsicana road, 2.5 miles north of Corbet, Navarro County; Corbet road, 3.8 miles southeast of Drane, Navarro County; gullies southwest of Drane road, 1.5 to 2 miles northwest of Corbet; secondary road past Eureka School, west of Big Creek bottom, 6.1 miles east of McClanahan, Falls County; roadside ditch 2.5 miles south of Ben Hur, Limestone County; roadside ditch about 1 mile northwest of Ben Arnold, Milam County; gully north of Buckholtz road, 8 miles west of Cameron, 1 mile west of Pettibone Station, Milam County; Buckholtz road, 0.75 mile west of Pettibone station.

Some idea of the broad extent of sea bottom favorable to the existence of *Exogyra cancellata* in the western Gulf region may be had from the fact that the shells of this species have been collected from the Saratoga chalk where it has been brought to the surface by structural uplifts on the flanks of the Prothro and Rayburn salt domes in Louisiana, 115 miles south of the normal belt of outcrop of the chalk in Arkansas, and from clay and marl exposed on the flanks of the Palestine and Keechi salt domes in Anderson County, Texas, a maximum distance of 50 miles east of the normal outcrop of the zone in that state. These localities are: two localities on Prothro salt dome, one in Sec. 18, T. 14 N., R. 6 W., and the other in the same township about 2,000 feet west of the "saline" on the line between Sections 7 and 8, Bienville Parish, Louisiana; Rayburn salt dome, on east side of the "saline" near center of Section 31, Bienville Parish, Louisiana; Keechi salt dome in gullies about 700 feet south of the main fault (as mapped by Sidney Powers), slightly east of the center of the R. R. Powers Survey, Anderson County, Texas; Palestine salt dome, from exposure at the northeast end of Dugeys Lake, Anderson County, Texas.

Three typical shells of *Exogyra cancellata*, in the collections of the United States National Museum, from Ciudad del Maiz, and one from near Cardenas collected by Bruce Wade, both localities in the state of San Luis Potosi, Mexico, show the extension of the zone for a distance of more than 400 miles south of the international boundary in that country. The bed that yielded the Cardenas specimen occurs in the lower part of a thick section of Upper Cretaceous sediments.

The facts given indicate that during the Upper Cretaceous epoch, in terms of the European section probably late in Campanian or early in Maestrichtian time, sediments were laid down on the bottom of a sea whose waters spread along the eastern side of the American

continent at least from the Navesink Highlands of New Jersey to the state of San Luis Potosi, Mexico, a distance along the present line of outcrop of the sediments of approximately 2,500 miles (Fig. 1). Although the belt of outcrop of these sediments is interrupted in several areas by extensive overlaps of younger sediments, the presence of at least one species of the oyster family, *Exogyra cancellata*, in the sediments at both ends of the bed, and at many intermediate localities, indicates that the continuity of this sea was not interrupted by any strongly projecting land salients.

Associated with *Exogyra cancellata* are many other species of mollusks and other marine organisms, whose geographic range is known to be from New Jersey to the Gulf region, and notable among these are several other members of the oyster family. A list of the more common species of the mollusks follows.

SPECIES OF EXOGYRA CANCELLATA ZONE THAT RANGE FROM NEW JERSEY TO GULF REGION

Ostrea teticosta Gabb
O. plumosa Morton
O. falcata Morton
O. panda Morton
Gryphaea mutabilis Morton
Exogyra cancellata Stephenson
E. costata Say
Pecten simplicius Conrad
Anomia argentaria Morton
A. tellinoides Morton
Paranomia scabra (Morton)
Veniella conradi (Morton)
Cyprimeria depressa Conrad
Turritella trilira Conrad
Belemnitella americana (Morton)

Only two of the species listed, *Exogyra cancellata* and *Anomia tellinoides*, are restricted in their stratigraphic range to the *Exogyra cancellata* zone, but the fact that this assemblage of organisms could have lived and thrived together throughout so great an extent of sea, indicates that the food supplies and the temperature and salinity of the water were fairly uniform from one end of the belt to the other. However, if some adaptability of the organisms to environmental differences is assumed, these conditions need not have been absolutely uniform, and that they were not is shown by the fact that many organisms living in parts of the zone are limited in their geographic range along the zone. When the faunas have been critically studied and analyzed, it will doubtless be possible to divide the belt into half a dozen or more faunal provinces or subprovinces.

That the climate in the Gulf region was tropical during the time of the formation of this zone is indicated by the presence in Texas of rudistids, a group of organisms that are believed to have lived in tropical waters. It therefore seems reasonable to conclude that climatic conditions from the Gulf region on the south to New Jersey on the north were not colder than subtropical.

The sediments composing the zone are sands—generally glau-

conitic,—calcareous shales, clay marls, and chalks. The thickness of the zone is variable from place to place, but ranges from 4 feet at the northern extremity of the zone in New Jersey to 200, or perhaps 300, feet in central Texas; the thickness has not been ascertained in the state of San Luis Potosi, Mexico.

The composition of the faunas contained in the *Exogyra cancellata* zone, particularly the large shells of *Gryphaea* and *Exogyra*, indicate that the sediments composing the zone were laid down in relatively shallow water. On the other hand, the general absence of cross-bedding in the sediments indicates that they settled in water that was too deep for waves and currents to disturb them as they reached their resting place on the sea bottom. The sediments were deposited on a continental shelf in water probably more than 15 fathoms, and less than 100 fathoms deep.

At the Navesink Highlands in New Jersey, the zone lies only about 30 feet above sea-level; it dips east and within less than a mile passes beneath sea-level and is covered by the waters of Raritan Bay and the Atlantic Ocean. Between New Jersey and the Carolinas the outcrop of the zone probably nowhere exceeds 60 or 70 feet above sea-level. The altitude of the outcrop in the Gulf region ranges from 300 to 600 feet above sea-level. In the vicinity of Cardenas, State of San Luis Potosi, Mexico, the zone has been uplifted by mountain-building forces to more than 3,500 feet above sea-level, and somewhere south of Cardenas is lost among the mountains and plateaus of the Mesa Central.

Throughout the vast extent of country from the Navesink Highlands of New Jersey to Cardenas, in the State of San Luis Potosi, Mexico, comprising 2,000 miles of plains and 500 miles of hills, mountains, and plateaus, the zone of *Exogyra cancellata* affords a reliable zone of reference for the determination of the age and stratigraphic relations of Upper Cretaceous beds both below and above it. When there has been added to the molluscan index fossils already mentioned as characterizing this zone, a few more companion species of *Foraminifera* or other microscopic fossils having a similarly restricted stratigraphic range—and such species will doubtless be found—the usefulness of the zone will have been greatly enhanced because of its easy recognition in well sections.

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SUGARLAND OIL FIELD, FORT BEND COUNTY, TEXAS[1]

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Houston, Texas

ABSTRACT

The Sugarland oil field overlies a moderately deep salt dome which arched the super-cap sedimentary beds. Evidences of several local unconformities, brought about by erosion of the crest of the cap rock and the overlying Vicksburg formation, and submarine erosion of the Middle Oligocene formation with resulting sedimentary texture changes, and local thinning of several formations are shown. Altogether, 1,256 acres have produced (March, 1933) 16,762,597 barrels of oil, or an average acre-yield of 13,226 barrels. The water line has closed in uniformly around the structure. In the fourth year of pressure maintenance the reservoir pressure is 1,345 pounds per square inch, as compared with 1,550 pounds originally. The observance of bottom-hole pressure phenomena in several edge wells suggested that the approach of edge water could be foretold.

INTRODUCTION

Location.—The Sugarland oil field is located in the Brazos River Valley in the east-central part of Fort Bend County, Texas. It is within the salt-dome province of the Gulf Coastal Plain, and the associated salt dome is a member of the Fort Bend-Harris-Brazoria County cluster of salt domes. The town of Sugarland is 4.5 miles north, and Houston is 18 miles northeast. The station of DeWalt on the Sugarland Railroad is 1 mile east from the east edge of the field. This oil field is an outstanding example of cleanliness and orderly exploitation. Although situated in the soft soils of the Brazos River bottom, the well drained, hard surfaced roads make access to any part of the field easy.

History of discovery.—Several years prior to the discovery of the Sugarland salt dome a dry hole was drilled by the Belvidere Oil Company (T. R. Sutherlin *et al.*) in a locality which later was developed into the east side of the oil field. This test, which must have encountered the Middle Oligocene formation, was abandoned in April, 1922, at a depth of 3,504 feet, only 181 feet above the top of the oil zone found in Nelson No. 7, situated 120 feet northeast. An earlier wildcat test drilled by the Walker Syndicate only 0.5 mile

[1] Read before the Association at the Houston meeting, March 23, 1933. Manuscript received, August 21, 1933. Published by permission of the Humble Oil and Refining Company.

[2] Geologists, Humble Oil and Refining Company.

north from the north edge of the oil field, was abandoned in May, 1921, at 3,810 feet. This test cored a saturated oil sand at 3,600 feet and because of this showing, the Gulf Production Company leased a block, made a seismograph survey without favorable results, and turned it back. The presence of a salt dome was shown later by torsion balances.

The Sugarland oil field was discovered by the initial test well drilled by the Humble Oil and Refining Company, Sugarland Industries No. 1, which was completed on March 27, 1928, flowing 800 barrels on $\frac{3}{8}$-inch choke. The well was completed in the sands of the *Marginulina* zone of the Middle Oligocene formation at 3,561 feet. This well is now beaned to 130 barrels daily. The associated moderately deep salt dome had been found in 1926 by Seismos torsion balances operated by H. C. Cockburn; and subsequently, the Humble acquired Cockburn's lease block for a consideration of $250,000 cash and 1/24 over-riding royalty interest. Contiguous leases were taken, of which the Camp and Hamner tracts later became productive, to complete the solid block over the structure.

Deductions following discovery.—The discovery of oil in gently arched sand sheets overlying the moderately deep[3] Sugarland salt dome revived activity in the search for oil occurring in similar conditions in the Gulf Coastal Plain. Oil fields on structure similar to Sugarland were discovered in the early days of Gulf Coast oil development at Batson and Saratoga, where the sands of the prolific Middle Oligocene formation were gently arched by an underlying salt intrusion. The great advantages of deep salt domes with arched, overlying sand sheets of large area to form perfect reservoirs was obvious. The presence of undiscovered salt-dome structures of the Sugarland type was, therefore, suggested by the Sugarland discovery.

The Sugarland discovery brought about a new phase of geophysical exploration for deep and moderately deep salt domes. The fact that the presence of salt domes of this class could be determined by seismographs initiated a new phase of seismograph exploration, and almost the entire Gulf Coast area was "re-shot" by the refraction method. In order to record shot-wave energy from deep and moderately deep salt domes, receiving stations were placed at greater distances from shot-points, 10–15 kilometers, and dynamite charges were increased to 800 or 1,000 pounds per shot. Since 1926, 59 salt domes, or salt-dome uplifts, have been either proved by drilling or

[3] See unpublished paper by L. P. Teas in the Association's forthcoming book, *Geology of Natural Gas*, for classification of types of salt domes by depth.

verified by positive, diagnostic geophysical phenomena. Of those discoveries, 43 lie at intermediate or greater depths.

Acknowledgments.—Appreciation is expressed to the Management of the Humble Oil and Refining Company for providing the means and extending permission for the publication of this study. To Wallace E. Pratt and L. T. Barrow, the writers are indebted for criticism and advice; to L. P. Teas and H. D. Wilde, Jr., for discussion and constructive criticism; and to Miss Alva C. Ellisor and the subsurface laboratory, for the nomenclature of the underground formations of the Gulf Coast. The structural contour map of the field was adapted from the office map prepared by C. R. Miller. Appreciation is expressed to J. A. Tomlinson of the civil engineering department, and to T. H. McCleary for their assistance in the preparation of the plates.

SURFACE

The surface formation overlying the Sugarland salt dome consists of post-Beaumont river-terrace deposits, which show no direct evidence of exceptional geologic structure. The terrace consists in large part of light reddish brown sandy and silty clay loam, classified as Yazoo soils by the United States Bureau of Soils.[4] The average yield of the rich virgin soil is a bale of cotton per acre. The source[5] of the Yazoo Terrace materials has been ascribed to probable denudation of the West Texas Permian evaporites drained by the headwaters of the Brazos River system, a theory which is here indorsed. The average elevation of the Yazoo Terrace is 70 feet, and the Beaumont Terrace[6] (Houston clay of the United States Bureau of Soils) which forms the prairie on the east, is 75 feet. The drainage, in consequence, is poor. The post-Beaumont age of the Yazoo Terrace is shown by its relatively lower level as compared with the Beaumont Terrace.

The mean annual rainfall is 46.22 inches, almost equally divided between the four seasons, and the mean temperature is 68.9°F.[7] The terrain is flat; and the region, therefore, is subject to normal, subhumid processes of erosion.

The relative levels of the Yazoo Terrace and the Beaumont Terrace maintain their normal positions at Sugarland.

[4] F. Bennett and Grove B. Jones, "Soil Survey of the Brazoria Area, Texas," *Field Oper. U. S. Bur. Soils* (*1902*).

[5] Donald C. Barton, "Surface Geology of Coastal Southeast Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 10 (October, 1930), p. 1318.

[6] Alexander Deussen, "Geology of the Coastal Plain of Texas West of Brazos River," *U. S. Geol. Survey Prof. Paper 126* (1924), p. 5.

[7] H. V. Geib, T. M. Bushnell, and A. H. Bauer, "Soil Survey of Harris County, Texas," *U. S. Bur. Soils* (1928), p. 1907.

The Sugarland salt dome is another illustration of the absence of direct surface indications in the Gulf Coast which would have led to the discovery of a salt dome. An unverified gas seepage was reported[8] in a shallow water well near a negro tenant's farm house.

GEOLOGICAL SECTION IN SUGARLAND OIL FIELD

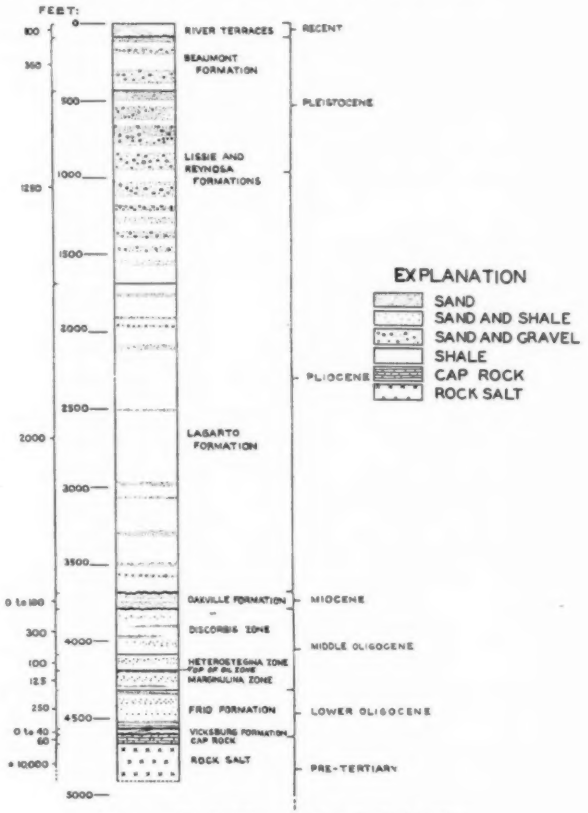

FIG. 1.—Typical Sugarland geological section.

SUBSURFACE

The Sugarland stratigraphic column consists of the sequence of sedimentary formations overlying the Vicksburg formation in this part of the Gulf Coast and the salt-dome petrologic subdivisions com-

[8] R. H. Goodrich, personal communication.

posed of calcitic limestone, massive anhydrite, and rock salt. An intermediate gypsum cap zone is probably absent.

PLEISTOCENE

Lissie[9] *and Beaumont*[10] *formations.*—From the surface down to 1,600 feet the section consists of alternations of sand, gravel, and varicolored mottled clay, with the percentage of coarse material almost equal to the clays. The separation of this group from the underlying clays is based on lithologic character. No appreciable thinning of these strata is manifest.

MIOCENE AND PLIOCENE

Oakville,[11] *Lagarto,*[12] *and Goliad*[13] *formations.*—Below the Lissie and Beaumont formations is a group of mottled red, blue, and greenish clastic sediments. Provisionally, the contact between the Pliocene (Lagarto and Goliad) and the Miocene (Oakville) in the Gulf Coast subsurface is based on lithologic character. The typical thickness of these formations is about 3,300 feet. At Sugarland they are thinned to 1,175 feet. Based on lithologic character, the Pliocene is in contact with the Middle Oligocene on the crest of the structure, and about 100 feet of gray "salt and pepper" Oakville sand is present on the slopes.

OLIGOCENE

Catahoula[14] *formation.*—The Catahoula formation is almost absent in the normal geologic column in the Sugarland region, and entirely absent in the Sugarland structure. The farthest down-dip extension of typical Catahoula yellowish green bentonitic clay in the typical position above the Middle Oligocene is at Mykawa, where it is less than 50 feet thick.

Middle Oligocene[15] *formation.*—The Middle Oligocene formation, so referred to by common usage, consists of olive and light and dark

[9] Alexander Deussen, "Geology and Underground Waters of the Southeastern Part of the Texas Coastal Plain," *U. S. Geol. Survey Water Supply Paper 335* (1914), p. 78.

[10] *Ibid.*, p. 80.

[11] Alexander Deussen, "Geology of the Coastal Plain of Texas West of Brazos River," *U. S. Geol. Survey Prof. Paper 126* (1924), p. 97.

[12] *Ibid.*, p. 100.

[13] Refers to a group of caliche-weathering, white, calcareous sandstones and intercalated vari-colored calcareous clays cropping out typically at Goliad, Texas, containing a brackish-water molluscoid and terrestrial vertebrate fauna of Miocene-Pliocene age, formerly a part of the Reynosa formation, the synonymy of which at present is unsettled.

[14] *Ibid.*, p. 95.

[15] E. R. Applin, A. C. Ellisor, and H. T. Kniker, "Subsurface Stratigraphy of the Coastal Plain of Texas and Louisiana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 1 (January–February, 1925), p. 102.

green shale and gray and greenish gray sands. Heavy and rare minerals are present in unique assortment. The three fossil zones, in descending order, *Discorbis*, *Heterostegina*, and *Marginulina*, however, do not contain diagnostic mineral species. Glauconite and pyrite predominate in the washed residues of the *Heterostegina* and *Marginulina* zones, and a relatively smaller quantity of glauconite is present in the *Discorbis* zone. In the *Marginulina* sands, clear, trans-

TABLE I

VARIABLE THICKNESS, IN FEET, OF MIDDLE OLIGOCENE ZONES AND FRIO FORMATION IN FOUR TYPICAL WELLS AT SUGARLAND

Well	*Middle Oligocene*			*Frio*	*Underlying Formation*
	Discorbis Zone	*Heterostegina Zone*	*Marginulina Zone*		
Sugarland No. 2	223	150*		388	Not penetrated
Camp No. 1	215	30	98	260	Cap rock
Nelson No. 6	313	20	164	41	Not penetrated
Deatherage No. B-1	300	105	96	184	Vicksburg

* Combined thickness of *Heterostegina* and *Marginulina* zones.

parent quartz grains predominate and some milky quartz is present. The *Marginulina* sands and sandy shales furnish a large part of the oil. The Middle Oligocene formation is divisible into its three faunal zones by paleontology solely. The *Heterostegina* zone, which contains coralline or foraminiferal limestone on neighboring salt domes, at Sugarland consists entirely of clastic sediments. The thickness of the Middle Oligocene formation varies from 343 feet to only 501 feet, though its normal thickness in the Sugarland region is 800 feet. In some parts of the Sugarland structure the Middle Oligocene and Frio formations compose the entire section between the cap rock and the Lagarto formation. The variable thickness of the three Middle Oligocene zones is shown in the cross section (Fig. 2) and in the logs of wells as shown in Table I.

Frio[16] *formation.*—The Frio formation consists of greenish gray, light-to-dark bluish green clays with lime nodules, and light gray sands, and white, fine, volcanic ash. The Frio sands contain several rare minerals, of which zircon predominates. Tourmaline, feldspars, and rutile complete the assemblage. In the washed residues most of the sands are cloudy, milky, polished medium and coarse quartz grains. The basal contact of the formation is a decided lithological contrast with the underlying Vicksburg, but its upper contact with

[16] A. C. Ellisor, "Correlation of Jackson Group in Texas, with Notes on Frio and Vicksburg," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 11 (November, 1933), pp. 1293–1350.

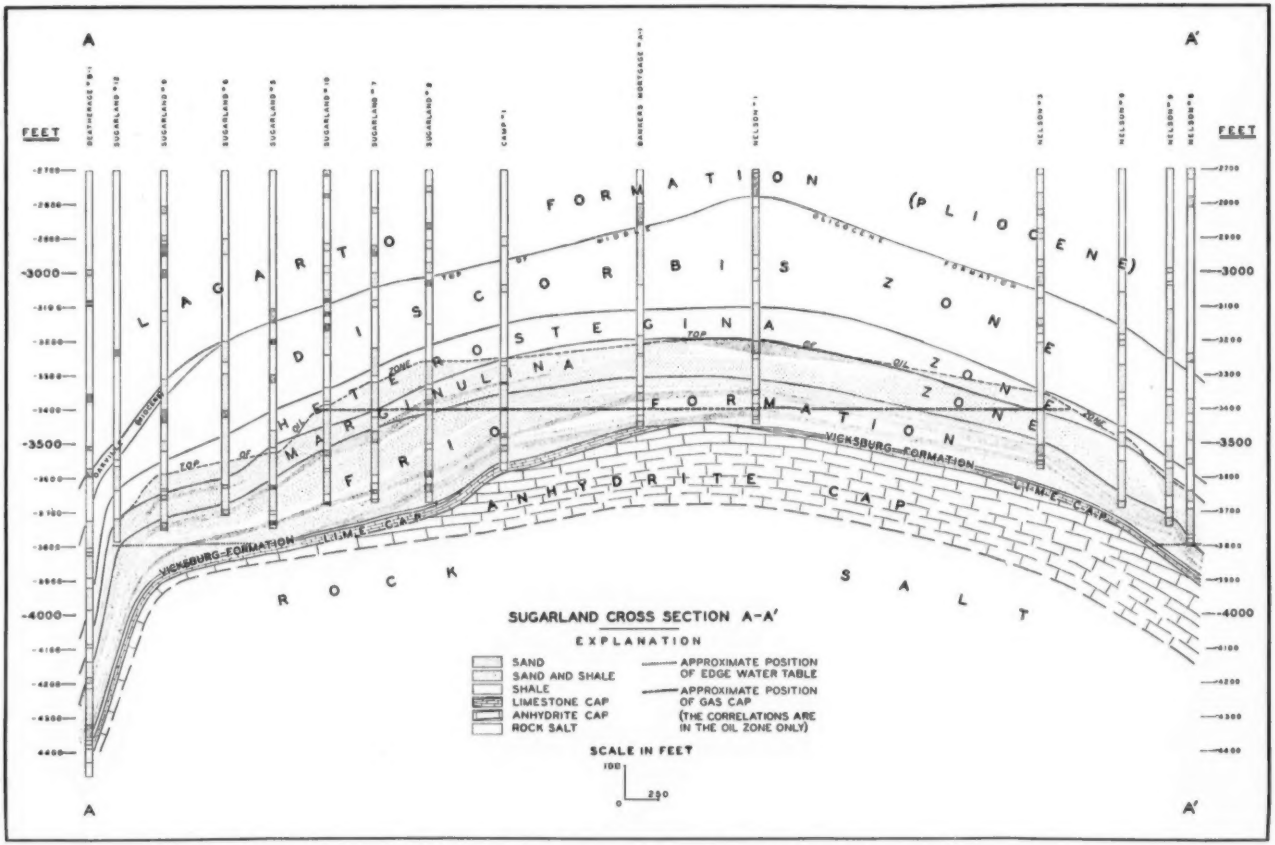

FIG. 2.—Northwest-southeast cross section of Sugarland.

the *Marginulina* zone of the Middle Oligocene is not distinguished in hand specimens because of similar lithologic character. Most of the Sugarland oil sands occur in the Frio formation. The Frio was unevenly planed off before the overlying Middle Oligocene was deposited, as shown in the cross section (Fig. 2) by the position of an upper Frio sand sheet, which is present over the west half of the structure. There are two well developed "blanket" sand sheets in the lower part of the Frio which extend over the entire structure. The Frio formation contains *Rotalia beccarii* var., *Elphidium* sp., and several other long-ranging *Foraminifera* but no diagnostic forms. The thickness of the Frio varies from 184 feet in Deatherage No. B-1 on the west edge to 388 feet in Sugarland Industries No. 2 on the west slope of the structure. It is more than 80 per cent thinner than its normal thickness of 1,800 feet in this region.

Vicksburg[17] *formation.*—The Vicksburg (Lower Oligocene) formation is present only on the slopes of the salt dome, extending to a feather-edge thickness up the structure (Fig. 2). The sharp lithologic change from the overlying predominantly green clays and light gray sands of the Frio in contrast to the brown and black carbonaceous, sideritic, pyritiferous shales and gray and light brown sandstones of the Vicksburg makes its recognition easy, although it is thinned to less than 5 feet near the apex. On the super-cap area, the Vicksburg formation thins and its well developed faunas decrease accordingly, a large *Haplophragmoides* species and several other arenaceous and calcareous non-diagnostic *Foraminifera* constituting the sparse fossil record. On the crest of the dome the formation is absent; in a well situated down the slope it is 40 feet in thickness. In Hamner Fee No. 3, two sand beds occupy 19 feet of the 32-foot Vicksburg formation, and in Dew No. 1, the formation consisted of 15 feet of sand and shale with a showing of oil. Nine other wells were drilled through the Vicksburg, in which were found 4–40 feet of shale. The normal thickness of the Vicksburg in the Sugarland region is more than 1,200 feet. It does not crop out in the Texas Gulf Coast, because it is overlapped up-dip from Sugarland.

FIG. 2.—Northwest-southeast cross section of Sugarland.

PRE-TERTIARY

Sugarland cap rock.—The cap rock has moderate relief. The dip is quaquaversal. The maximum thickness of the cap rock, 61 feet, was found in the deepest well in the field, Deatherage No. B-1, on the west slope. It is composed entirely of calcitic limestone and massive crystalline anhydrite. An intermediate gypsum zone is either

[17] A. C. Ellisor, *op. cit.*

relatively thin or entirely absent. No anhydrite sand has been found at Sugarland. The cap rock has not been drilled through on the crest of the dome; consequently, it may be more or less than 61 feet in thickness. The tests which have been drilled into the cap on the crest of the uplift usually stopped in the top of the cap rock, and no well penetrated it more than 36 feet. Only two tests, situated on the west

TABLE II

TABLE SHOWING CONTACTING SEDIMENTARY FORMATION, THICKNESS IN FEET OF CAP-ROCK ZONES, AND OF SALT PENETRATED AT SUGARLAND

Well	*Overlying Sedimentary Formation*	*Cap Rock*		
		Calcite Zone	*Anhydrite Zone*	*Rock Salt*
Hagenson No. 1	Vicksburg, 40	37	*	*
Deatherage No. B-1	Vicksburg, 7	13	28	40
Hamner No. 2	Vicksburg, 32	2	*	*
Hamner No. 4	Frio	None	11	*
Hamner No. 6	Vicksburg, 5	None	7	*
Dew No. 1	Vicksburg, 15	24	12	*
Dew No. 2	Vicksburg, 7	10	*	*
Camp No. 1	Frio	20	*	*
Camp No. 3	Vicksburg, 5	5	*	*
Bankers Mortgage No. A-1	Frio	8	*	*
Brazos Farms No. 2	Frio	21	6	*
Brazos Farms No. 3	Vicksburg, 13	15	8	*
Brazos Farms No. 4	Vicksburg, 4	6	*	*
Brazos Farms No. 5	Vicksburg, 10	6	*	*
Brazos Farms No. 6	Frio	None	5	*
Nelson No. 11	(No samples)	8	*	*
Deatherage No. A-1	Vicksburg, 24	17	44	22

* Was not penetrated.

slope, were drilled through the cap into salt; therefore, information concerning the cap-rock area is incomplete. The torsion balances show a minimum over the crest of the uplift, which indicates a relatively thin cap rock. Of the seventeen tests which were drilled to the cap rock, all but three found the sedimentary formations in contact with the usual topmost calcitic limestone zone. In the eight wells which encountered the anhydrite zone, it was found that no transitory gypsum zone separated the calcite and anhydrite zones. In three tests, on the crest and the west slope of the structure, the anhydrite itself was found to be in contact with either Vicksburg or Frio sediments. The cap rock is overlain by the Vicksburg formation on the lower slopes, and the Frio formation is in contact with it on its crest. The limestone zone contains showings of oil in places, but its relative thinness and denseness disqualify it as an important oil reservoir. No analysis of the cap rock is available. One salt core from an unknown depth contained 97.05 per cent by weight sodium chloride and 2.95

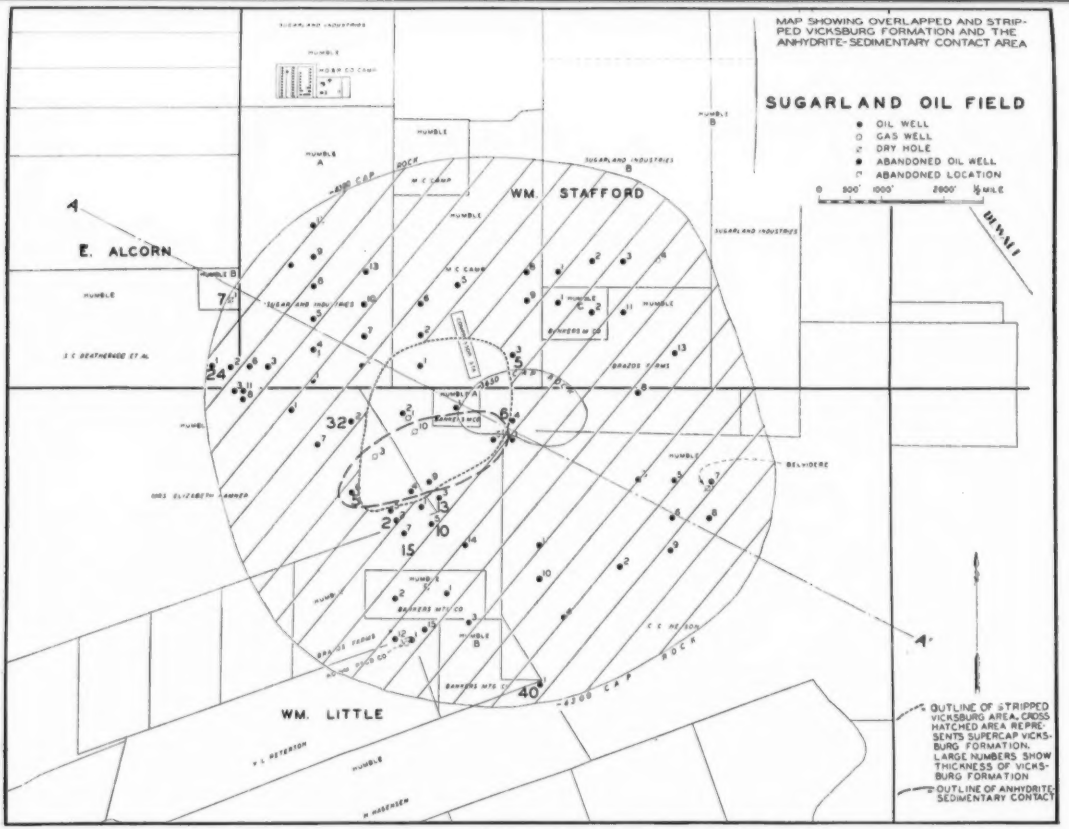
MAP SHOWING OVERLAPPED AND STRIPPED VICKSBURG FORMATION AND THE ANHYDRITE-SEDIMENTARY CONTACT AREA
SUGARLAND OIL FIELD
OIL WELL
GAS WELL
DRY HOLE
ABANDONED OIL WELL
ABANDONED LOCATION
0 500' 1000' 2000' ½ MILE
WM. STAFFORD
E. ALCORN
WM. LITTLE
OUTLINE OF STRIPPED VICKSBURG AREA. CROSS HATCHED AREA REPRESENTS SUPERCAP VICKSBURG FORMATION. LARGE NUMBERS SHOW THICKNESS OF VICKSBURG FORMATION
OUTLINE OF ANHYDRITE-SEDIMENTARY CONTACT

FIG. 3.—Map showing area of stripped calcite cap and Vicksburg formation.

per cent by weight anhydrite. No significant showings of sulphur were found in the cap.

An extraordinary condition is the contact of the anhydrite zone with either the Vicksburg or the Frio sedimentary formations on the crest of the cap rock in an area of about 80 acres. On the slopes, the calcite zone is in contact with the sedimentary formations and overlies the anhydrite zone. The exposure of the different cap-rock zones

TABLE III

GENERAL SOUTHEAST TEXAS GULF COAST STRATIGRAPHIC SECTION

Group	*System*	*Formation*	*Zone*	*Average Thickness in Feet*
Quaternary	Recent			300
	Pleistocene	Beaumont clay Lissie sand		1,600
Tertiary	Pliocene	Goliad (Lafayette) Lagarto (Fleming)		500 2,800
	Miocene	Oakville		
	Oligocene	Catahoula		50
		Middle Oligocene	*Discorbis*	400
			Heterostegina	600
			Marginulina	400
		Frio		1,800
		Vicksburg		1,200

to sedimentary formations suggests that the lime cap rock had been consumed in part by erosion prior to or during the periods of deposition of sedimentary formations. In this sense, the apex of the cap-rock area was eroded sufficiently to expose the basal anhydrite zone. It was later covered by the Vicksburg formation, which in turn was completely stripped from the apex of the growing salt intrusion and partly removed from the slopes, allowing further erosion of the limestone and anhydrite zones from the crest during a later period (Fig. 3).

SOUTHEAST TEXAS STRATIGRAPHIC SECTION

The ordinary sequence of formations found in any wildcat test off the Sugarland salt dome is shown in Table III.

STRUCTURE

Most of the stratigraphic knowledge of the Sugarland structure necessarily is restricted to the 1,256-acre arched area of the petroleum reservoir overlying the highest part of the cap rock. As shown by the contour map, the petroleum reservoir is a dome dipping at almost the

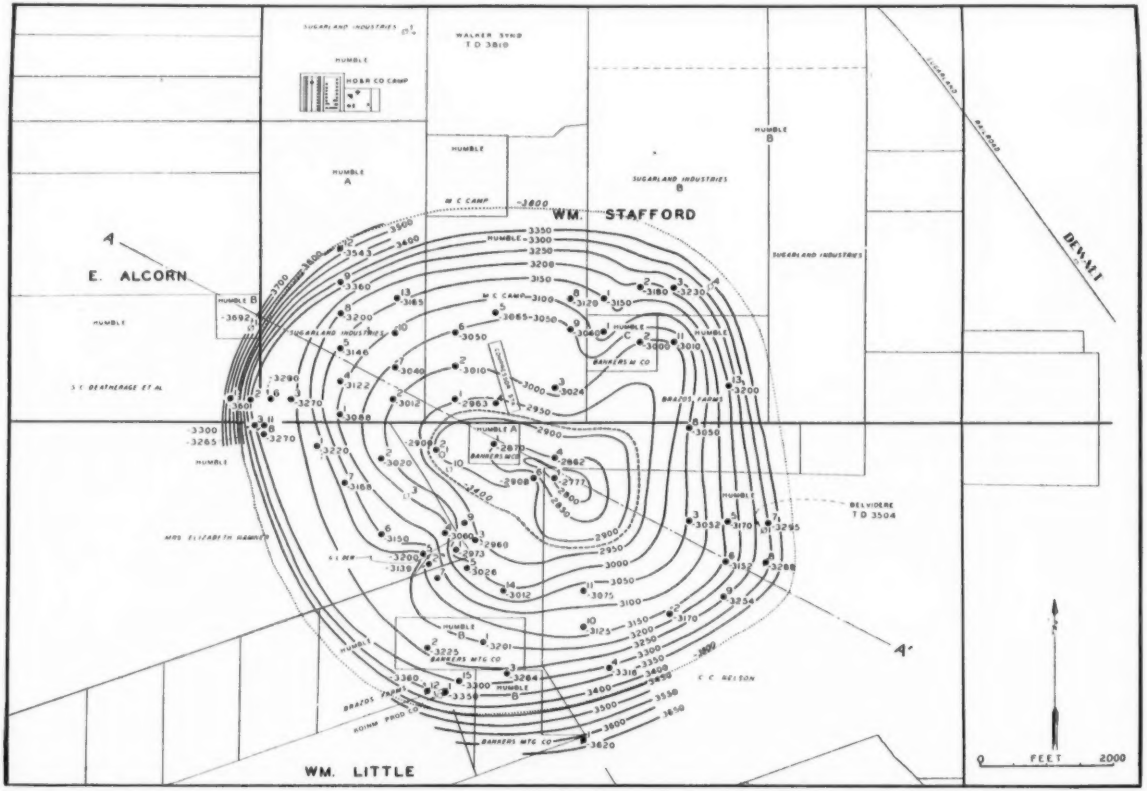

FIG. 4.—Sugarland oil field structural contour map on top of *Discorbis* zone of Middle Oligocene. Dotted contour (−3,800), outline of edge water. Broken contour (−3,400), outline of free-gas area. Well symbols, same as Figure 3.

same rate in all directions from the apex. Although the Middle Oligocene formation was uplifted more than 2,000 feet, the petroleum reservoir as reflected by the *Discorbis* zone, curiously enough, in spite of great uplift, preserved a dome unbroken by faulting. The formations involved in the uplift were altered by the uplifting process contemporaneously with their disposition.

The relative uplift of the various formations is shown in Table IV.

TABLE IV

STRUCTURAL RELIEF ON TOP OF FORMATIONS INVOLVED IN SUGARLAND SUPER-CAP UPLIFT

Formation	*Feet*
Cap rock	At least 10,000
Vicksburg	4,100
Frio	2,500
Middle Oligocene	2,125
Miocene	2,000
Pliocene	125
Pleistocene	No uplift

Although the Middle Oligocene formation is uplifted more than 2,000 feet, only the upper 500 feet of the structure was filled with oil. The productive closure on the top of the oil zone is 500 feet.

EFFECT OF UPLIFT ON SEDIMENTATION

The formations and zones below the Pleistocene are thinned considerably on the structure.

TABLE V

PERCENTAGES OF THINNING OF FORMATIONS IN SUGARLAND UPLIFT

Formation	*Normal Thickness (Feet)*	*Average Sugarland Thickness (Feet)*	*Per Cent Thinned*
Cap rock	?	61	*
Vicksburg	1,200	40	97
Frio	1,800	300	83
Middle Oligocene	800	425	47
Catahoula	50	Absent	100
Oakville, Lagarto, and Goliad	3,300	1,175	65
Lissie and Beaumont	1,600	1,600	0
Tertiary and Quaternary	8,750	3,540	60

* Possible thinning of the cap rock is reflected in the absence of a gypsum zone.

These local differences in formation thicknesses on the dome compared with the normal, off-structure section indicate that various ranges in depth of deposition, caused by many local uplifts and contemporaneous erosion followed by burial of sediments, ensued from the time when the Sugarland salt dome was first covered by sedimentary formations.

REGIONAL GULF COAST STRUCTURE

The regional structure of the Gulf Coast is a homocline composed of many wedge-shaped strata which increase variably in thickness toward the Gulf of Mexico, and some of which are overlapped. The younger strata have a gentle rate of dip, and the older strata have a progressively steeper rate. The slope of the youngest formations corresponds with the gradient of the youthful land surface, which is less than 4 feet per mile southeast.

SALT-INDUCED STRUCTURAL MOVEMENTS ASSOCIATED WITH SUGARLAND

The thirteen salt domes in eastern Fort Bend and northern Brazoria counties are situated in an orderly northeast trend along parallel lines. The distance between domes is approximately 5 miles. The Sugarland salt dome is situated in an arcuate trend described by the locations of several shallow salt domes extending from West Columbia northeast and eastward past Barbers Hill. If the cover of post-Middle Oligocene could be removed, there could be seen a terrain whose relief would be comparable with that of the present Appalachians.

UNCONFORMITIES ON SUGARLAND DOME

Diastem type of unconformity.—On the Sugarland salt dome, as well as on all other salt domes, local unconformities are clearly and easily apparent where close well drilling has provided the opportunity to examine the sequence of formations. Some of the unconformities necessarily are of local development by reason of local planing off and contemporary redeposition over or around the flank of the salt intrusion. In this case, several feet of sand on the structure may represent a great basinward thickness of shale and sandy shale. Such intraformational terminations of sand occur between Camp No. 1 and Bankers Mortgage No. A-1, and Sugarland No. 8 and Sugarland No. 5, as shown on the cross section (Fig. 2). In the Sugarland super-cap area, the thinning of the Vicksburg and Frio formations and the Middle Oligocene zones, represents localized unconformable conditions. The salt dome was overlain by five sand sheets of localized occurrence. Some of these sand sheets were deposited as fringing strands, and others, as intraformational sand bodies. In all probability, these sands were deposited by local sorting of coarse particles through the agency of submarine currents washing against a shoal or ridge, during Frio and Middle Oligocene time. Contemporaneously, these formations were deposited in greater thicknesses with sparse sand con-

tent in the off-shoal regions. The five sands represent five local pulsations in the deposition of sediments, which were caused by salt uplifting the floor of the sea. For the local unconformable conditions thus brought about, their classification as "diastems"[18] seems appropriate.

Angular unconformities.—The hiatuses of several disconformities and regional unconformities are accentuated by local uplift and planing of considerable thickness of many formations. The absence of 65 per cent of the normal Miocene-Pliocene thickness, and the contact between the top of the cap rock and the overlying Frio and Vicksburg sediments, which represents a hiatus of more than 10,000 feet, are the expressions of accentuated regional unconformities. The contacts between the Frio and Middle Oligocene sedimentary formations and the Middle Oligocene zones are unevenly planed, disconformable surfaces. The sands have been considerably modified by these disconformities and unconformities; in some places, large areas of sands have been entirely removed during the erosion interval between deposition of the several formations and zones (Fig. 2). There is, therefore, a distinction between the two types of unconformities which during their genesis directly affected the future qualities of the petroleum reservoir. Diastems were wholly concerned in providing sands for porosity and drainage; angular unconformities were concerned only with the removal, during a later period, of parts of sand sheets deposited during a diastem interval.

The removal of sand sheets during erosion intervals does not mean that the structure contains less oil than it would have otherwise; but significance lies in the fact that porous media suitable for drainage are absent, which otherwise would have been present. Erosion of the several formations overlying the cap rock are discussed in the following paragraphs.

Vicksburg formation.—The Vicksburg formation overlapped an eroded cap-rock surface and it consists of a mere remnant of its normal thickness. It was completely removed from an area of 150 acres on the apex, and almost entirely removed from the slopes of the super-cap area (Fig. 3). Its maximum thickness of 40 feet was found on the south part of the super-cap, in Hagenson No. 1. On the west edge, the Vicksburg is between 7 and 24 feet thick, in Deatherage No. 1-B and Deatherage No. 1. Approaching the apex, in Hamner No. 2 and Dew No. 1, the Vicksburg lithologic character changes from massive shales to sand and shale.

[18] Joseph Barrell, "Rhythms and Measurements of Geologic Time," *Bull. Geol. Soc. Amer.*, Vol. 28, No. 4 (1917), pp. 789 *et seq.*

Frio formation.—During the early part of Frio time, the remaining Vicksburg formation overlying the uplift was almost entirely stripped. The progress of erosion continued through old age before the region was again downwarped sufficiently to permit the top of the salt dome to be covered by a part of the Frio sediments. The Frio formation was exposed to erosion, a considerable part of its thickness having been consumed on the slopes of the fold. This is shown by a comparison of its thickness on the west slope, where it is 170 feet thick,—though on the crest it is 260 feet thick,—with its thickness on the opposite slope, less than 160 feet. The three Frio sand sheets, aggregating 90 feet, represent an unknown greater thickness of contemporaneously deposited shales and sandy shales in the normal off-structure section. The planing of the Frio formation removed at least 50 per cent of its on-structure thickness from the east half of the structure. The plane of this unconformity also removed an important oil-producing sand which is present in the west half of the structure.

Marginulina zone.—The *Marginulina* zone decreases in thickness over the apex of the dome. It is 170 feet thick on the southeast slope, 100 feet on the apex, and 150 feet thick on the northwest slope, showing that it was either planed off or was variably overlapped over the uplifting structure. As shown in the cross section (Fig. 2), a good sand section in the vicinity of Nelson No. 1 at the top of the *Marginulina* zone was stripped from the upper part of this zone.

Heterostegina zone.—The *Heterostegina* zone is thinnest over the northwest and southeast slopes of the structure; it ranges from 30 feet on the northwest slope to 120 feet on the crest, and 20 feet on the southeast slope. The *Heterostegina* zone was arched by the salt uplift after being planed off. This zone does not contain sand sheets, although the top of the oil zone occurs in the northwest part of the structure in this zone.

Discorbis zone.—The *Discorbis* zone shows plainly unequal erosion over the top of the structure after its deposition. Its apical thickness is three times the thickness on the southeast and northwest slopes.

Upper Miocene.—There is about 100 feet of Oakville formation on the west slope, which constitutes the entire thickness of the Miocene at Sugarland. This represents a considerable hiatus, for the Miocene has a normal thickness of 2,000 feet in the region. It is not certain whether this hiatus was accomplished through erosion of a thick Miocene section, or by non-deposition of the Miocene over the uplift; possibly a thin Miocene interval was deposited and later reduced.

HISTORY OF UPLIFT

As recorded by unconformities, the Sugarland salt-dome growth was initiated prior to Tertiary and continued through Miocene time. Prior to the Vicksburg stage, a large part of the salt uplift was either a submarine or subaerial knoll, dating from pre-Tertiary time; indeed, possibly older formations covered it and had been stripped. The top of the cap rock was considerably eroded prior to its burial in the Vicksburg sediments, as evidenced by the contact of sedimentary formations with the normally lowest anhydrite cap-rock zone over the apex. After the Vicksburg formation was deposited, the dome again was brought above the plane of deposition of the ensuing early Frio seas, for during that time the greatest part of the Vicksburg formation was stripped from the crest of the uplift. Possibly at this period the highest calcite zone was eroded down to the anhydrite zone, for the area of the stripped calcite zone is almost coëxtensive with the stripped part of the Vicksburg (Fig. 3). The stripping of the Vicksburg formation and the calcite cap zone was evidently the result of subaerial or submarine erosion contemporaneous with structural uplift, for these zones thin out up the slope of the dome, and possibly some Vicksburg sand zones also show the angular unconformity. The Frio and Middle Oligocene formations were also considerably reduced. These formations were planed after deposition, but the greater part of their attenuation was more probably accomplished by means of local submarine or subaerial erosion, within the planes of many small disconformities (diastems). During the *Heterostegina* period, the top of this salt dome was certainly in relatively shallow waters, which inhibited the growth of coral reefs, such as those which flourished on the neighboring West Columbia and Damon Mound salt domes. During Miocene time, possibly the uplift was a barrier upon which little or no sediments were deposited. The salt growth had almost completely subsided at the beginning of Pliocene time, since nearly the entire Lagarto formation was deposited.

A summary of the tectonics involved in the Sugarland uplift follows.

1. The entire Gulf Coast region was downwarped several different times below sea-level.

2. While the Gulf Coast region was being downwarped, the Sugarland salt continued to grow upward in many pulsating movements. The rate of the salt uplift, however, sometimes was slower than the rate of regional downwarp, which accommodated the several sedimentary overlaps.

3. In spite of regional downwarping of the Gulf Coast plain, the

Sugarland salt dome continued to grow upward through late geological time.

4. Since the beginning of Vicksburg time, the Sugarland salt dome has been the scene of a series of oscillations which alternately brought its crest above or depressed it below the planes of subaerial erosion, submarine erosion, and submarine deposition, the aggregate periods of uplifting being in the ascendency.

5. The Sugarland salt dome is now in a stage of quiescence which dates back to early Pliocene. In contrast, the salt uplift at the neighboring Blue Ridge salt dome has progressed through fairly recent time, as evidenced by relatively shallow cap rock.

RESERVOIR CONDITIONS

The reservoir at Sugarland is made up of a zone of sandy shales and sands with seemingly impervious shale lenses. The average thickness of the oil-bearing section is 300 feet. In a reservoir of this type it would be expected that there would be indirect migration of the oil through the reservoir, or indirect connection of all the oil-bearing members of the reservoir. The facts that tend to prove this are the uniform gravity of the oil throughout the field, and the uniform performance of the wells, depending on the structural position almost entirely.

There are four sands in the reservoir that are continuous in the larger part of the field. The average thickness of clean oil sand is 90 feet for the field. By the use of a peg model, cross sections, and the study of individual well histories a reasonably accurate correlation of the sands shows their relationship in different parts of the field.

The fourth or lowest sand lies directly above the cap rock on the highest part of the structure with a gradual increase in thickness of sandy shale or shale between it and cap rock toward the flanks of the dome. This sand is absent in some wells, and was not reached in drilling in most of the edge wells, but evidently extends through nearly the entire field, ranging in thickness from a few inches to 50 feet.

The top of the third sand ranges from 25 to 100 feet above the fourth. Its thickness also ranges from a few inches to 50 feet. It is absent in some wells. The combined thickness of these two sands rarely exceeds 50 feet in any well.

The second sand is consistent on the north and west sides of the field and lenses out near the highest part of the structure. Its top is rarely more than 50 feet above the third sand, and it ranges in thick-

ness from almost nothing to 20 feet. In places it is absent. In most wells where recognized, it is about 15 feet thick.

The first sand occurs less uniformly than any of the other three and is recognized only in the northwest part of the field. It is made up of two sand members separated by thin sandy shale. Its total thickness is about 40 feet.

The two lower sands are by far the most consistent, and they furnish the best wells. However, the discovery well was made in the upper sands, and it is still flowing 130 barrels daily, 5 years after its completion.

The sands and sandy shales found in the Vicksburg formation in two wells are not considered as important present oil-producing members of the reservoir; consequently, they were not included in this discussion.

The average porosity of the oil sands is estimated at 25 per cent.

The relative thinness and denseness of the lime cap disqualifies it as an oil reservoir, although showings of oil occur there.

The position of edge water in all sand sheets is almost at the same level. The salt water and oil contact does not overlap up the structure in any sand beyond the water level of overlying or underlying sand sheets.

PETROLEUM DEVELOPMENT

During the years 1928, 1929, and 1930, 70 wells were drilled. Sixty-six were completed as oil wells, one as a dry gasser, and 3 were dry holes, 2 of which went into salt and one into cap rock. Of the 66 oil wells, 3 have been abandoned because of edge-water encroachment, 2 have been temporarily abandoned, 3 are used as gas-injection wells, and 61 are capable of producing oil through purposely reduced chokes (Fig. 4).

Proration has been maintained since the field's discovery, thereby conserving gas, and making it necessary to pump only a few wells in the field.

With one exception (G. L. Dew lease), the leases were large enough to practice uniform well spacing. If the wells had been equally spaced, the average would have been one well to 18.5 acres, as compared with one well to 0.3 acre at Spindletop and an average of one well to 2.06 acres for the entire Gulf Coast salt-dome producing area. As there are only eight leaseholds in the field, development is simplified. The operators have endeavored to develop the field with a minimum waste of gas and a maximum recovery of oil through the smallest number of wells consistent with utmost recovery and the greater return to operator and royalty owner alike.

DRILLING METHODS

The rotary drilling system was used in developing the Sugarland field. The usual equipment used included two 72 horse-power boilers, draw works, 26-inch rotary, two 12-inch by 6-inch by 16-inch slush pumps, 10-inch by 10-inch twin-cylinder steam drilling engine, 122-foot steel drilling derrick, and 4-inch drill pipe with two joints of 6-inch drill on the bottom. Due to the relatively shallow depth, heavy-type rotary rigs were not used.

The common practice for casing was to set about 2,000 feet of 10-inch for a safety factor in event of a gas blow-out, and between 3,030 feet and 3,765 feet of 7-inch just above the first oil showing, dependent on the location of the well on the structure. The wells range in depth from 3,441 feet near the center of the field, to 3,812 feet on the edge. In the earlier stages of development, $13\frac{3}{8}$-inch casing was used for surface string and 10-inch for the oil string.

Drilling began with a 14-inch hole until 10-inch surface casing was set, then a $9\frac{5}{8}$-inch hole until it became necessary to begin coring for the oil sands. The remainder of the well was drilled with either a $6\frac{1}{8}$-inch core barrel or $6\frac{1}{8}$-inch fish-tail bit.

The completion method was to set 5-inch screen through the entire oil section, ranging from 49 feet to 430 feet, with 2-inch galvanized tubing spaced from 5 feet to 20 feet off bottom for the flow string. In about half the wells a full string of galvanized 5-inch liner was set. The wells were brought in through chokes, usually a $\frac{3}{8}$-inch, and turned through separators immediately after cleaning, with the loss of very little oil. Most of the wells would come in with their own pressure as soon as the mud was replaced with water.

After the completion of the wells they were equipped with a 96-foot standard pumping derrick with concrete foundation and floors.

PRESSURE MAINTENANCE

Sugarland furnishes ideal conditions for pressure maintenance, because the structure contains blanket sands and is operated by a single company. In order to determine the possibility of a plant capable of handling the gas produced with the oil, a temporary plant of two compressor units was installed to record the induction pressure of the sands and the reaction of the gas on the wells. It was found that the wells would take appreciable amounts of gas at a pressure of about 1,400 pounds per square inch. All reactions appeared favorable to pressure maintenance and a plant was erected at a cost of $312,550. It was designed to return 4.4 million cubic feet of gas daily to the reservoir.

A gas-gathering system was installed and connected with all wells in the field. High-pressure separators were used to furnish the gas to the station at 50 pounds pressure in order to eliminate one stage of compression. The first stage of compression takes the gas at 50 pounds pressure and relays it to the second stage at 400 pounds pressure by means of six 100 horse-power compressors, having capacity of 4.4 million cubic feet daily. The second stage takes the gas at 400 pounds and returns it to the reservoir at about 1,400 pounds pressure by means of four 100 horse-power compressors having a daily capacity of 4.8 million cubic feet.

The purpose of this plant is to maintain as near as possible the original reservoir pressure. No attempt has been made to preserve the original reservoir pressure, but by returning to the reservoir gas that otherwise would have been wasted, to keep at all times pressures sufficiently high to flow the oil.

The plant went into operation on April 2, 1930, and since that time 3,170 million cubic feet of gas has been returned to the sands, or 89 per cent of the total produced. It is estimated that 700 million cubic feet has been used as fuel for developing the field. All the gas now being produced, about 1.9 million cubic feet daily, excepting a very small amount used for fuel, is being returned to the sands. The cost is between 7 and 8 cents per 1,000 cubic feet, or about 2 cents per barrel of oil produced.

RESULTS OF PRESSURE MAINTENANCE

Three wells located on the high part of the structure are now used as key wells: Brazos Farms No. 4 and No. 6, and Nelson No. 1. These wells penetrated the entire oil section, and were chosen in order that the injected gas should be taken by any or all of the oil sands. The gas injected on the structural "high" is not absorbed by the oil, because the oil is already saturated, so that the centrally situated free-gas area has increased. The increase in area of the central free-gas "bubble" was not uniform over the top of the structure, as had been expected; but it was brought about through a tendency of the gas to by-pass into areas of lower pressure. This by-passing effect was probably due to the travel of gas more freely through some of the sands, and the wells having been drilled to similar stratigraphic levels. The migration of the gas has been mostly in an easterly direction, because the pressure gradient is less on the east side of the structure than on the west.

The gas injected is definitely proved to have accumulated in the upper part of the oil zone, and a distinct line of separation lies be-

tween the oil and free gas. This has been shown by setting packers below the depth where free gas occurs and producing from the bottom of the well with a lower gas-oil ratio. The gas probably works through the lower sands to the low-pressure areas and rises to the upper sands.

Some of the wells on the lower slopes of the structure were tried for injection wells. These wells took the gas at a slight increase of injection pressure, but the gas injected was in excess of the amount that could be absorbed by the oil, and it channelled up to the high part of the structure. This channelling effect was noted by an increase of gas in wells between the induction wells and the free-gas area. In channelling back, the gas spread out in a fan shape over several hundred feet and most of it was produced as excess gas, before reaching the higher part of the structure.

By maintaining the reservoir pressure, it is expected to flow at least 90 per cent of the ultimate recovery by keeping enough gas in the reservoir to saturate the oil completely, and increase the ultimate recovery by having high pressure through a longer period. Under conservation, withdrawals of oil have been at a rate which is not faster than the uniform closing in of edge water.

Since this is the first salt-dome oil field on which any attempt has been made to maintain the reservoir pressure, no comparative data are available as to the results that have been gained at Sugarland. The reservoir pressure has decreased about 160 pounds, with the production of 5,376,084 barrels of oil, during the 24 months prior to the injection of gas. During the 3-year period since injection began, the decrease has been about 45 pounds, with the production of 11,619,334 barrels. The average bottom-hole pressure now is about 1,345 pounds as compared with 1,550 pounds originally. Prior to this conservation program, the reservoir yielded 33,600 barrels of oil per pound of expenditure of reservoir pressure, during a 2-year period. Since the beginning of the conservation program, the reservoir has yielded 259,000 barrels of oil per pound of expended reservoir pressure, during a 3-year period.

Concrete results of the pressure maintenance program may be seen in the slight increase of the central free-gas area since the discovery of the field 4 years ago. This increase is due to the excess gas produced outside of the free-gas area having been returned to the reservoir in the central gas area. The effect, therefore, has been for the oil outside of the central gas area to hold in solution its original gas, and prevent its migration up the structure to the central free-gas area, as it would have done if the pressure had been released. This,

together with the proration program, results in the conservation of enough gas energy to flow the oil and permit uniform closing in of the edge water.

BOTTOM-HOLE PRESSURE PHENOMENA

In the earlier development of Sugarland very little notice was made of bottom-hole pressures. The average bottom-hole pressure, calculated from the shut-in pressure of some of the wells, was 1,550 pounds per square inch, or equal to the hydrostatic pressure exerted by a column of water for the average depth of the wells, or 3,580 feet. When the first bottom-hole pressure readings were taken they were less than 1,550 pounds, because of the removal of oil and gas and consequent variable rates of equalization of the edgewise hydrostatic pressure through the oil-laden sands.

During 1932 marked changes in the pressure were recorded on the west and southwest sides of the field, which corresponds with the area of the greatest removal of oil and the fastest encroachment of water. Hamner No. 8 increased during the period from April through August, 1932, from 1,402 pounds to 1,515 pounds, while Sugarland No. 1, directly up the structure (Fig. 4), decreased from 927 to 613 pounds. Bankers Mortgage No. B-1 increased during this period from 900 to 1,256 pounds, while Brazos Farms No. 14, up the slope, increased from 798 to 876 pounds. A powerful water drive is therefore exerted on the west, southwest, and northwest sides of the field, but as yet is negligible on the east side.

By reason of having a water drive from all sides of the field and free movement of water and oil through the reservoir, the bottom-hole pressures as a whole should nearly equalize. In a well or two, not drilled into the Frio section, the bottom-hole pressures are low, which may be explained by the fact that the Middle Oligocene has relatively fewer sands present off the flanks of the structure and does not crop out, and the water drive may have to come from the Frio, which contains a large amount of sand, and does crop out. The migration of water pressure from the Frio to the Middle Oligocene through contiguous sands and sandy shales, being slower than the rate of removal of oil from the Middle Oligocene sands, causes a pressure drop.

The water drive is considered an important factor in the future production by closing in on all sides and flushing the oil from the sands as well as equalizing the bottom-hole pressures.

CLASSES OF PRODUCTION

The productive area is divided into three classes, namely, the free-gas area, the intermediate area, or oil area, and the edge zone.

Free-gas area.—The free-gas area occurs on the apex of the structure between the depths of 3,130 and 3,400 feet. It contained originally 167 acres. Wells completed in this area above 3,400 feet will produce dry gas. When the entire oil section is penetrated, oil from the lower sands will have a tendency to reduce the gas ratio when the upper gas sands are screened. All wells in this area produce an amount of gas greater than that absorbed by the oil. Recently, packers have been set cutting off the upper sands and producing from the lower sands with a lower gas-oil ratio.

TABLE VI

ANALYSIS OF SUGARLAND CRUDE PETROLEUM

Gravity, 27.9° Bé. Viscosity, 54 seconds at 100°F.
Basic sediment and water, 0.2% Sulphur, 0.13% Color, dark brown

POTENTIAL YIELDS

Product	*Per Cent*
400 end-point naphtha	13.6
Gas oil	36.4
Lubricating oil distillate	26.0
Bottoms (fuel oil)	22.0
Distillate loss	2.0
	100.0

Intermediate area.—The intermediate or oil zone circles and underlies the free-gas area. It contained originally 879 acres between the depths of 3,400 and 3,650 feet. In wells in this area the entire oil section could be screened without danger of water or excess gas. No free gas is produced. This area is gradually decreasing, as the free-gas area expands and the water line closes in.

Edge zone.—The edge zone, or oil and water area, forms the boundary around the field between the depths of 3,650 and 3,800 feet. The original water level was 3,800 feet. This area contained 200 acres, and wells drilled below 3,800 feet made water at completion. The salt-water plane varies, now being lowest on the northeast, at 3,790 feet, and highest on the northwest, at 3,700 feet; on the south it is 3,775 feet.

SUGARLAND PETROLEUM

Some of the edge wells on the Sugarland Industries' property produced oil of less than 25° Bé. All other leases produce petroleum of more than 25° Bé. gravity, varying from 26° to 29°. The general run of Sugarland crude shows an average of 26 per cent lubricating stock. An analysis of average crude from Sugarland is shown in Table VI.

PRODUCTION ESTIMATES

Until March 1, 1933, the Sugarland field had produced 16,762,597 barrels of oil, an average of 253,979 barrels per completed well, or 13,226 barrels per acre. The ultimate recovery per acre is estimated to be in excess of 50,000 barrels for the 1,255 productive acres. This compares favorably with the 40,600 barrels per acre recovered from all productive acres on the Gulf Coast salt domes. The field now produces its prorated allowable of 7,500 barrels per day with about 2 million cubic feet of gas. The gas-oil ratio is approximately 310.

SUMMARY

The Sugarland structure is unique in several geological features and in its exploratory and drilling development. It was the first of the deep and moderately deep salt domes found by geophysical methods over which large sand sheets were arched to form a petroleum reservoir. Sugarland is, also, the first almost completely drilled salt-dome structure where conservation was practiced from the beginning, and where accurate formation samples have been taken and exploration and development records have been maintained. These have served as a basis for a better understanding of the geological processes involved in the forming of the structure. Such processes include the making of extremely localized minor unconformities (diastems), and local accentuation to angularity of several disconformities and regional unconformities, accompanied by changes in sedimentary textures. Moreover, each of the pre-Pleistocene formations and zones involved in the uplift has been considerably thinned by subaerial or submarine erosion. However, any loss in thickness has been compensated by exceptional local development of several sand sheets, which form the petroleum reservoir.

Sugarland was the first entire salt-dome oil field where maintenance of reservoir gas energy was undertaken. Results of the conservation program are shown by a slight drop in reservoir pressure, the maintenance of a central gas "bubble" back-pressure area, and the natural flow of all but three of the wells. Each producing well has repaid its individual investment.

The exceptionally sharp increases in bottom-hole pressures in certain producing wells on the west side of the field presaged the advance of the water table.

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GEOLOGICAL NOTES

DEFINITION OF COCOA SAND MEMBER OF JACKSON FORMATION[1]

In 1925 some *Foraminifera* that had been sent to J. A. Cushman from the United States National Museum were described by him under the title "Eocene Foraminifera from the Cocoa Sand of Alabama."[2] Although the name Cocoa sand apparently had never before been published, it was used without definition or explanation other than that it is of upper Eocene (Jackson) age and that it occurs at Cocoa Post Office, Alabama. Since then several references to the Cocoa sand have appeared in print, all apparently traceable back to Cushman's paper. The latest to come to my attention is in P. J. Pijpers' "Geology and Paleontology of Bonaire (D. W. I.)."[3]

As Cushman's paper was based on specimens that he had not collected himself and with whose stratigraphic occurrence he was not acquainted by personal observations, he doubtless used the formation names that he found on the field labels. It is quite likely that the lot sent him included collections that I made in December, 1914, from a bed to which I then applied the field name Cocoa sand. Although I did not intend to publish this name and did not use it in the "Geology of Alabama" or other papers, it seems desirable to define it now that it is coming into use.

The name is taken from the abandoned country post office called Cocoa that many years ago stood in the SW. ¼, Sec. 13, T. 11 N., R. 5 W., Choctaw County, Alabama, about 2.5 miles east of Melvin on the road to Gilbertown. The following section, in which bed 1 represents the typical Cocoa sand, is adapted from "The Age of the Ocala Limestone."[4]

SECTION HALF MILE SOUTHWEST OF COCOA, ALABAMA

[Oligocene: Vicksburg group; Red Bluff clay]

4. Concealed. Exposures elsewhere in vicinity show that above bed 3 is yellowish-brown argillaceous marl containing *Spondylus dumosus* and

[1] Published by permission of the director, United States Geological Survey.

[2] *Cushman Laboratory for Foraminiferal Research Contributions*, Vol. 1, Pt. 3 (1925), pp. 65–69.

[3] *Rijksuniversiteit te Utrecht geog. en geol. mededeelingen, physiog. geol. reeks*, No. 8 (1933), p. 43.

[4] Charles Wythe Cooke, *U. S. Geol. Survey Prof. Paper 95* (I) (1915), p. 116.

Ostrea vicksburgensis, overlain by gray-to-yellow clay with crystals of gypsum and many Red Bluff fossils.

[Eocene: Jackson formation]

	Feet
3. Drab clay containing irregular calcareous concretions in lower part, about	10
2. *Zeuglodon*-bearing bed. Gray or drab sandy and argillaceous marl with harder ledges and irregular calcareous concretions; very argillaceous in upper part; about	11
1. [Cocoa sand member] Fine yellow sand with soft white calcareous lumps and large irregular lumps of hard yellow sandy marl. Grades upward into bed 2	6

The following generalized section of the Jackson formation in Choctaw County, Alabama, adapted from the "Geology of Alabama,"[5] shows the stratigraphic position of the Cocoa sand member.

GENERALIZED SECTION OF JACKSON FORMATION IN CHOCTAW COUNTY, ALABAMA

	Feet
5. Calcareous clay	25
4. *Zeuglodon*-bearing bed; yellowish or grayish marl with ledges; *Ostrea trigonalis*, *Ostrea falco*, *Schizaster armiger*, *Pecten spillmani*,* *Zeuglodon*, and other fossils	11–15
3. Cocoa sand member. Fine yellow sand, partly calcareous and argillaceous, with shells in lower part	17–70
2. Light green plastic calcareous clay with shells; in part micaceous and sandy	30–50
1. *Periarchus*-bearing bed (*Scutella* bed of previous papers). Ledges of gray indurated marl; *Pecten spillmani*, *Periarchus pileus-sinensis*, and other fossils	1–10

* Called *Pecten perplanus* in the original section. *Pecten spillmani* Gabb has been thought to be a synonym of *P. perplanus*, but the name *P. perplanus* Morton was originally applied to the flat valve of *P. poulsoni* Morton, which is unknown in deposits older than the Vicksburg group, and therefore is a synonym of *Pecten poulsoni*.

It is quite likely that the Cocoa sand member extends westward a short distance into Mississippi. It probably represents part of the Yazoo clay of Mississippi, which appears to be equivalent to beds 2 to 5, inclusive, of the generalized section in Choctaw County, Alabama. Bed 1 of the section is of the same age as the Moodys marl.

C. WYTHE COOKE

WASHINGTON, D.C.
September, 1933

BEEKITE IN TERTIARY OIL-BEARING FORMATIONS OF SOUTHERN ECUADOR

W. Campbell Smith, of the British Museum (Natural History), has kindly identified the mineral beekite, found by the writer in the

[5] Charles Wythe Cooke, "The Cenozoic Formations," in "Geology of Alabama," *Alabama Geol. Survey Spec. Rept. 14* (1926), p. 274.

Eocene formations of Ecuador, the associations and history of which are here described.

In Ecuador, beekite is found commonly along the fracture planes

FIG. 1.—Nodular mass *in situ*, Seca shales, Ancon, southwestern Ecuador.

of large nodular masses which occur in the Seca shales, of Eocene age. These shales are exposed in the coast sections between Ancon and Chanduy, in the Province of Guayas, and they also crop out inland

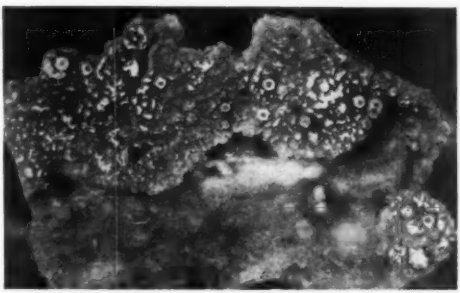

FIG. 2.—Beekite vein showing both mammillated and crystalline forms of silica ($\times\frac{1}{4}$).

where the river valleys are deep enough to have exposed the Tertiary formations below the Quaternary. The Seca shales are relatively shallow marine, or estuarine, deposits, and include sandy silts with a few thin sandstone beds. The nodular masses, however, occur only

in association with the shales, and vary in size from a few inches in diameter to several feet, the latter being very striking on account of their exceptional size (Fig. 1). Upon fresh fracture, the matrix of the nodule is ordinarily buff in color, though the weathered surface is light gray or white. The latter variation in color is due, no doubt, to a superficial efflorescence of calcium carbonate, caused by conditions of tropical weathering; actually, however, the matrix is highly siliceous in chemical composition. In many nodular masses the thin

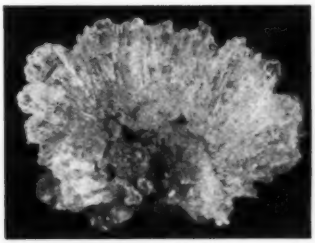

FIG. 3.—Fan-shaped outgrowth of quartz crystals (natural size).

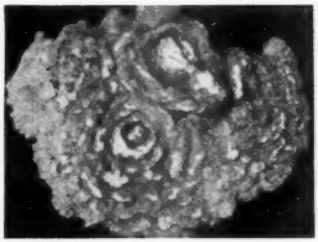

FIG. 4.—Mammillated form showing concentric arrangement of structure (natural size).

bedding planes of the country rock pass through the nodular structure, though some nodules appear without stratification and exhibit pronounced fracture planes only.

With the exception of fragments of fossil bone and a few foraminifers, the faunal content of the nodular masses is poor. It is extremely probable, however, that the bone fragments have been the initial cause of the structure. After exposure, the nodules exhibit a tendency to fracture in an exfoliating manner, the respective layers breaking off in large curved blocks. The beekite is found in the outer fracture planes, and by its growth in the vein cavity, or fissure, has assisted undoubtedly in the denudation of the nodule itself (Fig. 2). The mineral under discussion has the general appearance of a mammillated chalcedony, and it is a true vein product, the constituent silica having been leached from the matrix in the vicinity of the major fracture planes. Apparently there are two stages of growth which have materialized during the process of infilling the fissure: first, the crystalline variety, in the form of fan-shaped aggregations of pyramidal needles of quartz (Fig. 3), and second, the mammillated silica, in the habit of rosettes with a concentric structure (Fig. 4). The latter has probably originated as a stalagmitic form and, in

most places, has been deposited over the acicular crystals of clear quartz. The progressive growth of the chalcedonic form has occasioned lateral pressure upon the walls of the original fracture plane and, in several places, has directly caused the splitting of the rock folia from the parent nodular mass.

The writer's thanks are due to G. H. S. Bushnell, for permission to use the photograph reproduced in Figure 1.

GEORGE SHEPPARD

GUAYAQUIL, ECUADOR
September 12, 1933

ISLAND IN PERMIAN SEA[1]

Fossil plants have been secured from the Permian of the western interior at several localities. Another locality was recently uncovered during the drilling of The California Company's Currie No. 3 in northern Glasscock County, Texas. Cores from the upper Clear Fork limestone, below 3,600 feet in this well, contain numerous well preserved plant fossils. The best preserved specimen (Fig. 1) was exposed

FIG. 1.—Fossil fern from core of upper Clear Fork limestone.

by breaking a core parallel with the bedding. The plant tissue is carbonized and so soft that none of the venation is preserved, but the edges of the pinnules are entire and unfrayed. Because of the small size of the core only a 2-inch section of the frond was recovered. The fragment exposed is 1.5 inches wide at the widest point and tapers

[1] Published with the permission of The California Company.

very gradually. Seven pinna are present on each side. The largest one is 1 inch long and 0.3 inch wide.

David White[2] who examined the specimen reports that it is probably a fragment of *Gigantopteris americana*, a form characteristic of the lower Permian of Texas and Oklahoma. He further remarks:

I should add that while the fragment you transmit appears slightly macerated, it does not appear to have been damaged by wave action or long trans-

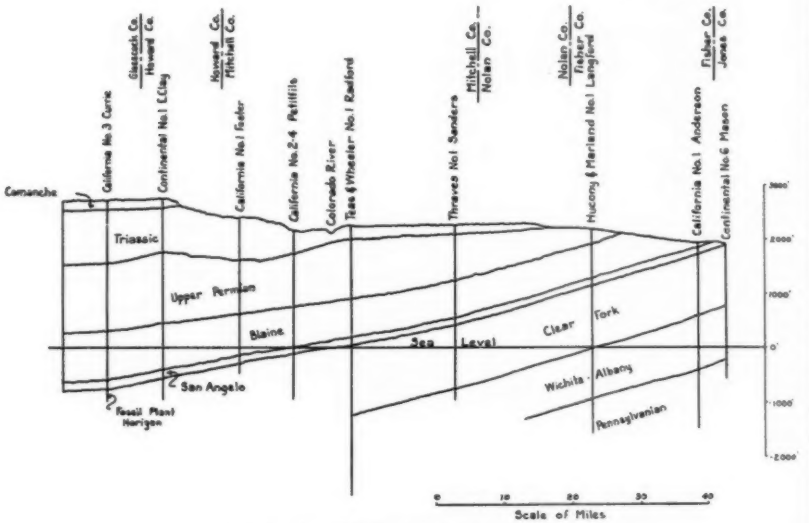

FIG. 2.—Stratigraphic section of eastern Permian basin showing horizon of fossil plants

portation. In fact, the fronds were subject to shriveling very readily and may easily appear to have shrunken as much as the fragment you submit. The back side of one of the pieces of core contains a number of fragments, some of which apparently belong to fern pinnules, though they are not sufficiently well preserved to permit identification. They also lack the degree of comminution, curling and laceration expected in such material if it has been beaten by waves or transported for long distances.

This fern came from a horizon about 200 feet below the top of the Clear Fork. The stratigraphy of the area is shown on the accompanying cross section (Fig. 2). The upper Clear Fork sediments encountered in the Currie well were evenly and thinly bedded, dark-colored, very carbonaceous dolomites. Fossil plant fragments, usually less well

[2] David White, personal communication.

preserved than the one shown, occurred throughout more than 100 feet of section.

Subsurface and field studies of the Permian stratigraphy strongly suggest that the eastern shore line of the Clear Fork sea was several hundred miles east of the Currie well at the time of leaf deposition. Examination of the leaves, secured from the cores, show that none of them could have undergone that much transportation. It is in fact very evident that they must have grown near the place in which they were buried.

Burial of these plants *in situ* may be accounted for in three ways. 1. In spite of the excellent evidence to the contrary, there may have been a very extensive retreat of the Clear Fork sea just at this time. The lack of any other evidence of such a withdrawal makes the theory seem highly improbable. 2. The ferns and other plants may have grown on a log raft which floated out to the northern Glasscock locality before breaking up. This might sound plausible if only one leaf had been found or if the plant remains had been limited to a single horizon. The presence of numerous well preserved leaves throughout many feet of limestone clearly discredits the log-raft hypothesis. 3. The ferns and other plants may have grown on an island. This last suggestion is supported by the fact that the Currie well is located on a structurally high area which was also high topographically during a considerable portion of the Permian.

If the area was an island slight local fluctuations during a period of regional subsidence could account for the accumulation of fossil plants through a great thickness of limestone. The plants would be preserved best in protected bays or lagoons and the even bedding of the limestone suggests such an area of deposition. In fact the insular theory explains the occurrence of the leaves so satisfactorily that there is little doubt of the existence of an island in the Currie area during upper Clear Fork time.

JOHN EMERY ADAMS

MIDLAND, TEXAS
October 4, 1933

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 17, NO. 11 (NOVEMBER, 1933), PP. 1394-1398

REVIEWS AND NEW PUBLICATIONS

Historical Geology. By RAYMOND C. MOORE. 649 pp.; 400 illus. 6×9. Cloth. McGraw-Hill Book Company, Inc., New York (1933). Price, net, $4.00.

This new college text book should be especially useful and interesting to members of the Association because an unusual proportion of the illustrative matter is taken from the Mid-Continent states, and because the author was editor of our *Bulletin* and has been very active in helping to guide our Association for many years.

Field workers in petroleum geology, having usually a limited area to investigate and limited kinds of observations to make, are likely to become indifferent to the broad aspects of historical geology and to forget matters that were intensely interesting to them as students and graduate workers. Moore's new book might well be added to the petroleum geologist's library as an up-to-date reference for practical use, as well as a stimulus to interests which should not be allowed to die.

The introduction explains to the student the methods of attacking the history of the earth, and clearly distinguishes between observed facts, speculations, hypotheses, and theories. The old hypotheses, such as those regarding continents and ocean basins, are presented, but also the newer ideas, such as the "floating continents" hypothesis and others. The exposures in the Grand Canyon are pictured, described, and interpreted as a means of understanding the historical significance of rock characters.

Each of the major periods of earth history is presented by giving first a bird's-eye view of the formations and physical history. This is followed by the general character and divisions of the rocks, and later by the discussion of distribution, type sections, and variations by regions or districts of North America. Deposits of other countries are then more briefly described. Next come more detailed interpretations of physical history, climate, economic resources, and a summary.

The treatment of typical life forms and their evolution results in a fairly continuous rather than badly interrupted story. Following the chapter on the Silurian period, fossils are explained, subdivisions of life are tabulated, and the life of "early Paleozoic time" is introduced and explained, as well as used for purposes of interpretation of history. Later, at the proper place, the life of late Paleozoic time is presented, and, similarly, that of Mesozoic time, and of Cenozoic time. This method of treatment seems to have advantages in an elementary text over that of treating separately the life of each period.

The book is very well illustrated, printed, and bound. The photographs, sections, block drawings, and other diagrams are selected from all parts of North America and the world at large. Although the Mid-Continent receives more attention than has been customary in such texts, and its problems of stratigraphy, correlation, and structure are presented exceptionally fully, this is an added attraction, especially for the oil geologist. However, there is no

lack of balance or neglect of classical localities. The book is admirably adapted as a text and also makes fascinating reading for a professional geologist.

F. W. DEWOLF

URBANA, ILLINOIS
September 9, 1933

"La geologie profonde de la France d'apres le nouveau reseau magnetique et les mesures de la pesanteur" (Subsurface Geology of France, According to New Magnetic and Gravimetric Surveys). By JEAN JUNG. From *Annales de l'Institut du Globe de l'Universite de Paris*, Vol. 2 (1933). 51 pp., 30 figs., 4 pls.

This treatise deals with the geologic interpretation of a recent magnetic survey of France conducted by the National French Council of Geodesy and Geophysics. The limited number of gravimetric measurements available is used to supplement and to check the magnetic survey.

Both magnetic and gravity measurements are found in greatest detail in the Alpine region. A profile of gravimetric measurements across the Alps reveals a wide negative centered at Göschenen with a sharper positive at Lugano. A profile of variations of Z in the same region shows a much more complicated result more in accordance with the surface geology. The author shows that the magnetic field is influenced by structure at a relatively shallow depth. It tends, therefore, to reflect surface structure. The anomalies of gravity have a more deep-seated origin and represent the condition of the basic magma.

In the Rhine valley a certain lack of correspondence existing between magnetic and gravimetric readings is found to be caused by the considerable thickness of sedimentary beds present in a restricted area. After the necessary corrections to the gravity readings, an excellent agreement is found between the two geophysical methods.

With two such widely varying interpretations of gravity readings as appear necessary in the Alpine region and in the Rhine valley it is obvious that very critical geologic inspection of the results is always necessary to avoid grave errors in interpretation.

Throughout the remainder of France a general agreement appears to exist between the two geophysical methods and the surface geology. A scarcity of data in most regions makes detailed study impossible, but shows that major structural trends are reflected by geophysics.

Several maps are included, showing interesting results obtained in various localities. A map is shown of the surface geology of France in relation to the magnetic anomalies.

The book is of special interest to those engaged in the interpretation of magnetic and gravimetric measurements over extended areas.

L. Y. FAUST
Geophysical Research Corporation

TULSA, OKLAHOMA
September 6, 1933

Petroleum Development and Technology, 1933. By the Petroleum Division. *Trans. Amer. Inst. Min. Met. Eng.*, Vol. 103 (1933). 29 West 39th Street, New York. 426 pp. Cloth. 6¼×9¼, outside. Price, $5.00 (Canadian postage, $0.60 extra).

The petroleum technologist's services were in unusual demand during 1932. The summary of his findings is recorded in Volume 103 of the Transactions of the American Institute of Mining and Metallurgical Engineers. The book is divided into five chapters, which deal with the following subjects: Stabilization, Economics, Production Engineering and Research, Production Statistics, and Refining.

The chapter on Stabilization points out the change in the conception of oil production from that of the "law of capture" to one of joint ownership and coöperative withdrawal of the reserves of oil and gas in a given pool. The common ownership of the gas energy and the legal difficulties of such a concept are stressed. A method by which each owner would be apportioned his just share of oil in the common pool is presented. The chapter is concluded with a description of proration during 1932 and the attempts at its enforcement.

In spite of the difficulty of attaining a balance between supply and demand, the attempt at proration resulted in an increase in the price of oil and in greatly improved company earnings. After this general statement regarding the financial record for 1932, the chapter on Economics reveals the possibilities of the future by a careful analysis of the demand for petroleum products and an appraisal of the existing supply. The conclusion is reached that overproduction in 1932 was no more severe and no more difficult of solution than it has been on several occasions in the past, and that the idea of over-supply has been exaggerated.

The necessity for extreme economy during 1932 stimulated engineering research, the record of which is summarized in Chapter III. The technology of deep-well drilling and control and the improvement in design of drilling and pumping equipment are recorded. New data have been furnished to the engineer regarding the reserves of oil and the best methods for its extraction through the measurement and interpretation of reservoir energy, improved apparatus for measuring the pore space in oil-bearing rock, and additional information regarding the solubility of gas in oil and the mechanics of fluid movements.

A comprehensive picture of the development of petroleum through the world is given in Chapter IV. Each state, province, or country is described by men familiar with the fields assigned them and the whole is summarized in a preface to the chapter.

The chapter on Refining records improved volatility of gasoline, further development of semi-vapor-phase cracking, the discovery of effective gum inhibitors, the extension of gasoline pipe-line systems, the blending of lubricating oil with gasoline, improvement in the consumption and manufacture of road oils, and development of corrosion preventatives.

H. E. ROTHROCK

TULSA, OKLAHOMA
October 2, 1933

RECENT PUBLICATIONS

AUSTRALIA

Report on Aerial Survey Operations in Australia During 1932, by W. G. Woolnough. Commonwealth of Australia Government Printer, Canberra (1933). 78 pp., 6 photographs, 2 maps. 8¼ × 13 inches. Paper.

GENERAL

An Introduction to the Study of Fossils, by Hervey Woodburn Shimer. Revised edition (1933). 496 pp., 207 figs. 5½×8 inches. The Macmillan Company, New York. Price, $4.00.

The Petroleum Register (July, 1933). 15th ann. ed. This important and convenient compendium of information that will save the time and increase the usefulness of members of the petroleum industry is concisely described on the title page as an

International annual directory, statistical record and equipment catalogue of the petroleum industry, with maps of the principal producing and prospective oil territories, presenting detailed reports of United States and foreign companies, including producers, refiners, marketers, jobbers, compounders, and grease manufacturers, natural gasoline operators, pipe lines, petroleum personnel, oil associations, and equipment manufacturers, also royalty companies, drilling contractors, and trade names. . . . Statistical section contains figures on production, consumption, imports, exports, and other important data.

457 pp. 9×11.5 inches. Cloth. Petroleum Register Corporation, 165 Broadway, New York. Southwestern Bureau, Dudley W. Moore, Box 1821, Tulsa, Oklahoma. Price, $10.00.

"Neue Gedanken über die Bildungsbedingungen und die Enstehung des Erdöls auf grund sedimentpetrographischer Untersuchungen" (New Notes on the Conditions of Formation and Origin of Petroleum on the Basis of Sedimentary-Petrographic Research), by Heinrich Müller. *Centrablatt f. Min.*, etc., Abt. B., No. 9 (1933), pp. 481–87.

"A Theoretical Analysis of Water-Flooding Networks," by Morris Muskat and R. D. Wyckoff. *Amer. Inst. Min. Met. Eng. Tech. Pub. 507* (1933). 30 pp., 11 figs.

"Contribution to the Knowledge of Sedimentary Volcanism in Trinidad," by H. G. Kugler. *Jour. Inst. Petrol. Tech.* (London), Vol. 19, No. 119 (September, 1933), pp. 743–72, 8 figs.

Catalogue of the Library of Dr. James Perrin Smith, on Geology, Paleontology and Related Subjects, Mineralogy, Zoölogy, Conchology, Biology, and Entomology. 70 pp. Lists 2,650 books and pamphlets for sale. Mrs. Frances Rand Smith, 1335 Cowper Street, Palo Alto, California.

On the Mineralogy of Sedimentary Rocks, by P. G. H. Boswell. A series of essays and a bibliography. Demy 8 vo., X+393 pp. Cloth. 5¾×8¾ inches. Thomas Murby and Company, London (1933). D. Van Nostrand Company, Inc., New York, Price, 21s, net.

GERMANY

"Historische Angaben über die ersten deutschen Erdölbohrungen" (Historical Statement on the First Drilling for Oil in Germany), by K. M. Blumenberg. First of a series. *Petrol. Zeits.* (Berlin, August 30, 1933), pp. 1–6; 2 figs.

KANSAS

"The Geology of Ness and Hodgeman Counties, Kansas," by Rycroft G. Moss. *State Geol. Survey of Kansas Bull. 19* (Lawrence, 1933). 49 pp., 7 pls. including 2 colored geologic maps. Price (mailing charge), $0.20.

"Grasses and Other Plants from the Tertiary Rocks of Kansas and

Colorado," by Maxim K. Elias. *Geol. Survey Kansas Contrib. Paleontology 1* (1933). 34 pp., 3 pls. Price, $0.05.

"Pliocene Diatoms of Wallace County, Kansas," by G. Dallas Hanna. *Geol. Survey Kansas Contrib. Paleontology 2* (1933). 26 pp., 4 pls. Price, $0.05.

KENTUCKY

"The Origin of the Asphalt Deposits of Western Kentucky," by William L. Russell. *Econ. Geol.*, Vol. 28, No. 6 (September–October, 1933), pp. 571–86, 2 figs., 1 table.

LOUISIANA

"Geology of Lafayette and St. Martin Parishes," by Henry V. Howe and Cyril K. Moresi. *Louisiana Dept. Conservation* (New Orleans) *Geol. Bull. 3* (1933). Illus. Bibliog.

TEXAS

"The Geology of Texas. Vol. I, Stratigraphy," by E. H. Sellards, W. S. Adkins, and F. B. Plummer. *Univ. Texas Bull. 3232* (1933). 1,007 pp., 9 pls., 42 figs., and geologic map in colors (scale, 1:2 million). Bureau of Economic Geology, Austin. Price, paper, $3.25; cloth, $4.00.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 17, NO. 11 (NOVEMBER, 1933), PP. 1399-1400

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to J. P. D. Hull, business manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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Jean Carson Finley, Shawnee, Okla.
Jess Vernon, Robert Brown, H. H. Kister

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Clinton R. Stauffer, W. H. Emmons, H. E. Zoller
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Dean Francis Metts, Houston, Tex.
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Withers Clay, Hibbing, Minn.
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ANNUAL MEETING

The nineteenth annual meeting of the Association will be held in Dallas, Texas, the latter part of March, 1934. Later announcements will give exact dates, hotel headquarters, and usual information.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 17, NO. 11 (NOVEMBER, 1933), PP. 1401-1402

Memorial

HARRY MAYO ANDREEN

Harry Mayo Andreen died at the home of his mother, Mrs. Emma Andreen, in Woodside, California, on June 23, 1933. The indirect cause of death was high blood pressure. Although it had been known for the past year among his most intimate associates that Andreen was rapidly failing in health and was not expected to live a normal term of life, still his death was a shock to his many friends. With his family he had departed from his home in Tulsa to visit his mother and other relatives and had been in California only a few days when death called him. He was buried beside the body of his father in Cypress Lawn Memorial Park, San Francisco, California.

To know Harry Mayo Andreen was to know a man of the most regular habits, a quiet, studious person, a conscientious, hard worker and one who enjoyed his home surroundings better than anything else. If Andreen had any hobbies, they were hunting and reading current magazines. His greatest recreation was to be comfortably settled in a favorite large green leather chair with a late magazine or technical book. On account of the state of his health in recent years, he never participated in athletics of any kind.

Andreen's commercial life started as a mining geologist and engineer; but like many geologists of a few years back, the higher salaries and romance of oil attracted him to a new field. He was born on May 16, 1891, in Woodside, San Mateo County, California, attended public school at Redwood City, and received his Bachelor of Arts degree in geology and mining from Stanford University in 1913. After leaving school, his first commercial work was in Alaska as an assistant assayer with the Alaska Treadwell Gold Mining Company. After holding this position a year, he was made a millman in the cyanide plant of the same company. In 1915–1916, he was retreatment foreman with the Alaska Gastineau Gold Mining Company. In 1917, he returned to the States and was associated with J. F. Newsom and C. H. Munroe until he joined the geological staff of the Southern Pacific Railroad Company as a field geologist, which position he held for two years. His service with the Southern Pacific Railroad Company trained him in a new field of work, petroleum geology. In 1919–1920, he joined the Roxana Petroleum Corporation, a subsidiary of the Royal Dutch Shell, and worked in their Rocky Mountain division. He affiliated with The Carter Oil Company in March, 1920, and continued with this company until his death. His service record with the Standard Oil Company of New Jersey subsidiary covered a period of approximately 13 years. Previous to 1926, Andreen was a field geologist with The Carter Oil Company, but since that date he had been in charge of the torsion-balance work in the geophysical department.

Andreen was elected to active membership in The American Association of Petroleum Geologists in August, 1927. He was a member of the American Institute of Mining and Metallurgical Engineers, as well as Masonic Lodges 168 A. F. and A. M. of Redwood City, California, Scottish Rite Consistory 1 of Cheyenne, Wyoming, and the Akdar Shrine Temple of Tulsa. He was also a member of the Boston Avenue Methodist Church of Tulsa, Oklahoma. He was married June 17, 1928, to Miss Ada Elizabeth Hardy, of Tulsa, of

which union there are two children, Anita Dolores, age 3 years, and Harry Mayo, Junior, age 1 year. Mrs. Andreen and the two children, of Tulsa, Oklahoma, Mrs. Emma Andreen, the mother, and Mrs. Grace A. Harrison, a sister, both of California, are left to mourn.

Photo by Rivkin, Tulsa, Okla.

HARRY MAYO ANDREEN

Although not prone to publish, or to speak in public, "Andy" was well known and will not be forgotten.

E. O. MARKHAM

TULSA, OKLAHOMA
September 22, 1933

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 17, NO. 11 (NOVEMBER, 1933), PP. 1403-1404

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

MELBERT E. SCHWARZ has severed his connection with the Rio Bravo Oil Company, Houston, Texas, and is now assistant teacher of petroleum engineering at Texas A. and M. College, at Lubbock.

W. H. WHITTIER, formerly of Santa Fe, New Mexico, is now special agent in charge of field parties of the division of investigations in the East Texas oil field for the Department of the Interior. His mail address is Box 146, Tyler, Texas.

R. C. BECKSTROM has received an appointment to assist in the work of the Civilian Conservation Corps, with the rank of captain. He is stationed at Chandler, Oklahoma.

A. S. HENLEY has changed his address from 1752 Kenneth Road, Glendale, California, to 401 Colquitt, Houston, Texas.

HAROLD F. MOSES, assistant manager with the Cia. de Gas y Combustible "Imperie" S. A., Tampico, Tamps., Mexico, until last April, sailed on October 5 for Turkey to do work in petroleum geology for the Turkish Government. His address is Iktisat Vekaleti, Ankara, Turkey.

GERALD S. LAMBERT, formerly with the Phillips Petroleum Company, Bartlesville, Oklahoma, is now in the geophysical department of the Shell Petroleum Corporation, Tulsa.

DAVID C. HARRELL, formerly of 604 Harris Avenue, Austin, Texas, is now employed with the Standard Oil Company of South America and may be addressed at General Ballivian, FCCNA, Provincia de Salta, Argentina, S. A.

HENRY SALVATORI, formerly with the Geophysical Service, Inc., Dallas, Texas, has formed his own company for operations of geophysical work in California. The new company is the Western Geophysical Company, with offices and laboratory at 950 South Flower Street, Los Angeles, California.

REX MCGEHEE, geologist, has recently been employed by the Shell Petroleum Corporation, with headquarters at Tulsa, Oklahoma.

CARLETON D. SPEED, JR., formerly at Corsicana, has recently been employed by J. B. Stoddard, an independent operator, with offices at 1514 Magnolia Building, Dallas, Texas.

A. E. MCKAY has changed his address from Box 2082, Tulsa, to Phillips Petroleum Company, Drawer B, Bartlesville, Oklahoma.

T. F. HARRISS, formerly of Honolulu, Hawaii, is assistant in the department of geology at Pomona College, Claremont, California, for the school year 1933–34.

The Midland Geological Luncheon Club, at Midland, Texas, recently elected new officers as follows: president, CHARLES A. MIX, California Oil Company; vice-president, JOHN E. ADAMS, California Oil Company; secretary-treasurer, ALDEN S. DONNELLY, Honolulu Oil Company, Midland, Texas. The club has an active membership of 24.

ERIC A. STARKE, chief geologist and director of exploration for the Standard Oil Company of California for 23 years, died at his home in Los Angeles, September 27, after a brief illness.

A. J. CHILDERHOSE, geologist for The Texas Company, has been transferred from Beeville to Corpus Christi, Texas. His address is 734 Nixon Building.

PAUL K. GOODRICH has changed his address from 1540 Garfield, Brownsville, Texas, to the Sun Oil Company, Dallas, Texas.

CHARLES S. HALL, of Tulsa, and DOLLIE RADLER, administrative geologist for the Amerada Petroleum Corporation, at Tulsa, were married October 9, 1933, at Bentonville, Arkansas.

J. LAWRENCE MUIR, recently engaged in research studies at the University of Oklahoma, has accepted a position on the geological staff of the Amerada Petroleum Corporation, with headquarters at Enid, Oklahoma.

W. P. JENNY, geologist and geophysicist, Houston, Texas, is the author of an article, "Structural Trends in Florida," which was published under the erroneous title "Geology of Florida not Favorable to Oil Accumulation," in the *Oil Weekly* of October 2.

The museum of the San Antonio section of the Association, located at 525 Milam Building, San Antonio, Texas, is one of the projects undertaken by the Association's committee on applications of geology, of which F. H. LAHEE is chairman. The museum, established about a year ago at the suggestion of HERSCHEL H. COOPER, is claimed to be the first sponsored by an official section or an affiliated society of the Association. It has a complete suite of lithologic specimens from the youngest Quaternary through the Tertiary and Cretaceous formations. A. W. WEEKS, 1118 City National Bank Building, San Antonio, is chairman of the museum committee.

The University of Texas Bureau of Economic Geology, E. H. Sellards, director, Austin, Texas, is receiving advance orders for Julia Gardner's "The Macro-Fossils and Stratigraphy of the Midway Group of Texas," which is completed in manuscript, but unpublished because of lack of funds. This monograph will be published if sufficient orders are received. The subscription is $2.00 per copy (cloth) or $1.50 (paper), to be paid upon request.

J. BROOKS KNIGHT, formerly of Peabody Museum, Yale University, New Haven, Connecticut, is now at Occidental College, Department of Geology, Los Angeles, California.